DOCUMENT RESUME

ED 182 128 SE 029 761

AUTHOR Bader, Morris
TITLE Solutions, Unit 5: Colligative Properties of Solutions. A Computer-Enriched Module for Introductory Chemistry. Student's Guide and Teacher's Guide.
INSTITUTION Illinois Inst. of Tech., Chicago.
SPONS AGENCY EXXON Education Foundation, New York, N.Y.; National Science Foundation, Washington, D.C.
PUB DATE 76
NOTE 69p.; For related documents, see SE 029 752-763; Not available in hard copy due to marginal legibility of original document

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Chemistry; College Science; *Computer Assisted Instruction; Computer Programs; *Higher Education; *Independent Study; Instructional Materials; *Learning Modules; *Science Education; Science Instruction; Simulation; Undergraduate Study
IDENTIFIERS *Computer Enriched Module Project

ABSTRACT

Presented are the teacher's guide and student manual for one of a series of self-instructional, computer-based learning modules for an introductory, undergraduate chemistry course. The student manual for this unit on the colligative properties of solutions includes objectives, prerequisites, pretest, discussion, and 20 problem sets. Included in the teacher's guide are implementation plans, answers to problems, software, a Mainline for Quiz Generating Program, the routine problem set program in FORTRAN, files program to store some basic chemical data in FORTRAN, sample run in BASIC, and 10 unit tests. (BT)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

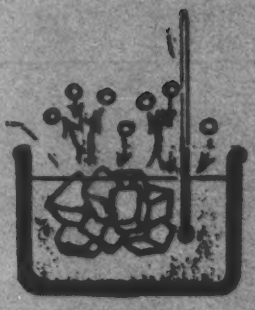
ED182128

SOLUTIONS

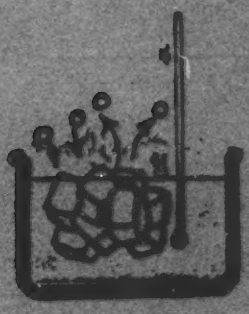
UNIT 5. COLLIGATIVE PROPERTIES OF SOLUTIONS

MORRIS BADER
MORAVIAN COLLEGE

A COMPUTER-ENRICHED MODULE
FOR INTRODUCTORY CHEMISTRY



pure water
freezing at 0°C



solution
freezing at -1°C

U.S. DEPARTMENT OF HEALTH
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Mary L. Charles
NSF

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Supported by grants from the
National Science Foundation
Exxon Foundation

Copyright by CM Publications 1976
Illinois Institute of Technology
Chicago, Illinois 60616

SE 029 761

OBJECTIVES

Upon completion of this module the student should be able to

1. understand such concepts as colligative properties, osmosis, and ionic dissociation.
2. calculate the effects of electrolytes and non-ionic solutes on boiling and freezing points of solutions and also the effects on osmotic pressure.
3. use Raoult's law to calculate vapor pressures above solutions.

PREREQUISITES

The student should be familiar with

1. latent heat of vaporization, heat of fusion.
2. vapor pressure and boiling points.
3. properties of gases.
4. use of concentration units such as molarity, molality and weight percent.
5. the phase diagram of a simple pure substance.
6. phase equilibria.

PRE-TEST

1. A 12 g sample of blue vitriol, $CuSO_4 \cdot 5H_2O$ is dissolved in 100 g of water. Calculate (a) the percent by weight of $CuSO_4$ in the solution and (b) the molality of the solution.
2. Calculate the molarity of a 500 ml solution containing 2.5 g of 98% by weight phosphoric acid, H_3PO_4.
3. In the modern space capsules oxygen is recycled from carbon dioxide by the reaction involving lithium superoxide, LiO_2 according to the reaction:

$$4\ LiO_2 + 2\ CO_2 \longrightarrow 2\ Li_2CO_3 + 3\ O_2$$

How many pounds of LiO_2 are required per pound of CO_2 removed?

Answers to pre-test:

1. (a) 7.67%
   (b) 0.048 molal
2. 0.05 molar
3. 1.77 lbs. LiO_2 per lb of CO_2

INTRODUCTION

Scientific discovery is very much like the building of a pyramid. At first there is an accumulation of facts and observations which seem totally unrelated. Like the stones of the pyramid, these facts must be sorted and laid out carefully and systematically until the shape of the final structure bocomes apparent. Thus facts and observations become transformed into theories and laws which in turn become the capping stones of scientific discovery. Elevated to these new heights one can see and understand a vastly broader view of nature.

In this module we will be concerned with the physical properties of chemical solutions. These properties are of great chemical and biological concern. Because they are mutually related they have been grouped together under the heading of "Colligative Properties". These properties are:

1. The Lowering of the Vapor Pressure
2. The Boiling Point Elevation
3. The Freezing Point Depression
4. The Osmotic Pressure

It would not be an exaggeration to speculate that these properties determine, to a large extent, the nature of life on this planet. For example, you might ask why the ocean waters at the North and South Poles don't freeze even though the temperature is below 0°C. Or ask why the fish, whose blood is over 85% water, manage to survive comfortably in the same frigid waters. Why does a man marooned on a raft eventually die from drinking sea water, while the kangaroo rat that lives in the desert can thrive on the saltiest of water? How do some trees that grow hundreds of feet tall raise water to the topmost leaves, when the best vacuum pump ever made can only raise water 32 feet? An understanding of colligative properties can provide answers not only to such questions, but in addition, can help us determine various chemical quantities including molecular weights and equilibrium constants.

DISCUSSION

A. The Effect of Solutes on the Phase Equilibrium

Let us suppose that a non-electrolyte, say sugar, or alcohol, is added to some water to form a solution. By non-electrolyte we mean a substance which does not dissociate in water to form ions, (non-ionic). In 1886 F. M. Raoult observed that the effect of this type of solute was to lower the equilibrium vapor pressure of the solvent in direct proportion to the mole fraction concentration of the solute. This relationship is known as "Raoult's Law".

$$P_1 = X_1 P_1^\circ \qquad (1)$$

where: P_1° = vapor pressure of pure solvent

P_1 = vapor pressure of solvent above solution

X_1 = mole fraction of solvent (water)

Note that the subscript (1) will be reserved for the solvent (water) and (2) for the solute. This distinction will be preserved throughout this module.

Since for a binary solution (one composed of two components only);

$$X_1 + X_2 = 1 \qquad (2)$$

Raoult's Law may also be expressed in terms of the solute concentration;

$$P_1 = (1 - X_2)P_1^\circ \qquad (3)$$

where X_2 is the mole fraction of the solute. Or,

$$\frac{P_1^\circ - P_1}{P_1^\circ} = X_2 \ . \qquad (4)$$

Letting $\Delta P = P_1^\circ - P_1$ the lowering of the vapor pressure of the solvent, then

$$\Delta P = X_2 P_1^\circ \qquad (5)$$

which is Raoult's original observation. If the solute does not have an appreciable vapor pressure at the temperature of the solution (a "non-volatile" solute), then the total vapor pressure above the solution is entirely that due to the solvent, $P_{total} = P_1$. On the other hand, if the pure solute has an appreciable vapor pressure at this temperature, then the total vapor pressure above the solution will be due to both solute and solvent, $P_{total} = P_1 + P_2$. If the solution is "ideal", that is, if the solute-solvent interactions are about the same as the solute-solute or the solvent-solvent interactions, then both the solute and the solvent will obey Raoult's law:

For ideal solutions:

$$P_2 = X_2 P_2^\circ$$

$$P_1 = X_1 P_1^\circ$$

$$P_{total} = P_1 + P_2 = X_1 P_1^\circ + X_2 P_2^\circ$$

Example 1. The molecular weight of methanol, CH_3OH, is 32 g/mol. Calculate the vapor pressure of water above a solution at 25°C composed of 40 g of methanol and 90 g of water. The vapor pressure of pure water at this temperature is 23.8 torr.

$$\text{moles } CH_3OH = \frac{40 \text{ g}}{32 \text{ g/mol}} = 1.25 \text{ moles}$$

$$\text{moles of } H_2O = \frac{90 \text{ g}}{18 \text{ g/mol}} = 5.0 \text{ moles}$$

mole fraction of water (solvent): $X_1 = \frac{5.0}{5.0 + 1.25} = 0.80$

Using Eq. (1): $P_1 = 0.80(23.8)$ torr

$P_1 = 19.0$ torr.

The total vapor pressure above the solution is due to both water and methanol, however.

Problem 1. How many grams of glucose, $C_6H_{12}O_6$, must be added to 72 g of water at 25°C to lower the vapor pressure to 20 torr? The vapor pressure of pure water at this temperature is 23.8 torr. The vapor pressure of glucose at 25°C is negligible.

B. The Effect of IONIC Solutes on the Vapor Pressure

The most interesting result of Raoult's investigations on the vapor pressure of solutions concerned the effect of ionic solutes. These solutes dissolve with the production of ions, and Raoult observed that each ion so produced is capable of acting as if it were an individual molecule obtained from a non-electrolyte. Thus, NaCl, dissolved in water dissociates 100% into Na^+ and Cl^- ions. Each of these ions acts independently. So, one mole of NaCl will give the same effect in lowering the vapor pressure of water as two moles of sugar or alcohol.

Let i_o be the number of ions produced by one molecule of solute. (i_o is generally referred to as the Van't Hoff i factor as it was he who put these results in quantitative form.) The i factor can be determined easily in most cases for simple solutes.

Ionic Solutes				i_o
$NaCl$	→	Na^+ +	Cl^-	2
$CaCl_2$	→	Ca^{+2} +	$2Cl^-$	3
$(NH_4)_3PO_4$	→	$3NH_4^+$ +	PO_4^{-3}	4
$Ca_3(PO_4)_2$	→	$3Ca^{+2}$ +	$2PO_4^{-3}$	5

For all non-dissociating solutes $i_o = 1$.

Problem 2. Calculate the Van't Hoff i factor for $Al_2(SO_4)_3$.

If we let N_1 be the moles of solvent and N_2 be the moles of solute, then, in order to correct for the effect of electrolytes we must multiply N_2 by i_o whenever it occurs in the expression for mole fraction, i.e.,

$$X_2 = \frac{N_2 i_o}{N_1 + N_2 i_o} \text{ for electrolytes} \qquad (6)$$

and

$$X_1 = \frac{N_1}{N_1 + N_2 i_o} \text{ for electrolytes} \qquad (7)$$

The vapor pressures may still be calculated by use of Eqs. (1), (2), (3), (4), and (5). The fact that the vapor pressure lowering depends mainly on the number of particles in the solution rather than their chemical nature is the reason for referring to vapor pressure effects and the effects to follow as "colligative properties".

Problem 3. Calculate the vapor pressure above a solution which is a 10% w/w $CaCl_2$ in water at 25°C. The vapor pressure of pure water at this temperature is 23.8 torr.

C. The Boiling Point Elevation

Assuming that a solute has been dissolved in water (ionic or non-ionic solute does not matter), let us examine the consequences of Raoult's Law on the phase diagram. In Figure 1 we see that the vapor pressure curve of the solution, EF, always lies below the vapor pressure curve of the pure solvent, BC, at every temperature. Since the lowering of the vapor pressure occurs at all temperatures, it produces a drastic effect on the boiling point of the solution. Notice that the pure solvent boils when the vapor pressure equals the external pressure. This occurs when the line BC crossed the 760 torr. At 100°C, however, the vapor pressure of the solution is still far below 760 torr, and so is not boiling. To get the solution to boil, it must be heated to the point where line EF, the vapor pres-

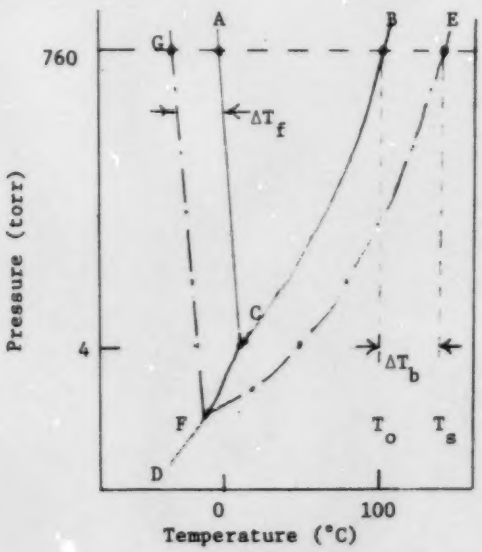


Figure 1. Phase diagram of pure solvent (———) and solution (–·–·–).

sure of the solution crosses the 760 torr line. This increase in temperature is known as the boiling point elevation, ΔT_b. The boiling point elevation is known to depend on the molality of the solute, so that

$$\Delta T_b = k_b m i_o \ , \tag{8}$$

where T_o = Boiling Point of pure solvent (K)

T_s = Boiling Point of solution

$$\boxed{\Delta T_b = T_s - T_o} \tag{9}$$

m = molality

k_b = molal boiling point elevation constant

i_o = Van't Hoff i factor

The quantity k_b, called the molal boiling point elevation constant, is a constant for any given solvent. Its value for water is 0.52 deg/m. The quantity k_b can be calculated for any solvent as follows:

$$k_b = \frac{RT_o^2}{1000\ \ell_v} \tag{10}$$

where: R = ideal gas constant, 1.987 cal/mol-deg

ℓ_v = heat of vaporization per gram (540 cal/g for water)

The quantity ΔT_b is the increase in the boiling point due to the solute. The molality, m, is a concentration unit we have seen before:

$$m = \frac{g(solute)}{g(solvent)} \times \frac{1000}{MW(solute)} \tag{11}$$

$$\text{or } \frac{moles(solute) \times 1000}{g(solvent)} \tag{12}$$

Example 2. Calculate the boiling point of a solution consisting of 14.2 g of sodium sulfate, Na_2SO_4, in 500 g of water.

a) The molecular weight of Na_2SO_4 = 142 g/mol.

b) The molality, m, by Eq. (11)

$$m = \frac{14.2 \times 1000}{500 \times 142} = 0.20 \text{ m} \ .$$

c) $i_o = 3$

d) Calculate ΔT_b by Eq. (8).

$$\Delta T_b = 0.52 \times 0.20 \times 3 = 0.31 \text{ deg}$$

e) Calculate T_s by Eq. (9).

$$T_s = T_o + \Delta T_b = 100 + 0.31$$

Ans. $T_s = 100.31°C$

Problem 4. The boiling point of benzene, C_6H_6, is 80.1°C and its heat of vaporization is 7,417. cal/mol.

a) Calculate k_b for benzene.

b) An unlabeled box of mothballs was known to be either naphthalene, $C_{10}H_8$, or paradichlorobenzene, $C_6H_4Cl_2$. A 20% w/w solution of moth-

balls in benzene boiled at 84.54°C. What was the correct label on the box?

Problem 5. The boiling point of a solution of 23 g of ammonium dihydrogen phosphate, $(NH_4)H_2PO_4$, in 400. g of water is 100.77°C.

a) How many ions are produced per molecule of the salt?

b) Write a balanced equation for the dissociation of the salt in water.

D. The Freezing Point Depression

Referring back to Figure 1 we recall that pure water freezes in an open beaker at point A, and freezes under its own equilibrium vapor pressure (the triple point) at point C. Now the important consideration is that when we cool a solution low enough so that any small amount of solid appears we use this observation to define the freezing point. For most solutions the solid that first appears is the pure solvent as the solute tends to lag behind in the solution before it too precipitates out in the solid phase. Thus if we follow the solution line EF as we lower the temperature, the point F represents the triple point between pure solid solvent, solution, and vapor. Since the vapor and the solid have no solute in them the intersection of line CD, the sublimation curve of the pure solvent, and the vapor curve of the solution EF, determines this new triple point F. The effect of increasing the external pressure on the solution solid-liquid equilibrium from slightly below 4 torr to 760 torr (1 atm.) is to bring the freezing point of the solution, in an open beaker, to point G on the diagram. The consequence of these equilibria is to lower or depress the freezing point of the solvent from point A to point G. Thus, the freezing point of a solution, T_s, will always be less (remember that) than the pure solvent, T_o. Notice that ΔT_f, the lowering of the freezing point, is a negative number:

$$\Delta T_f = T_s - T_o \ . \qquad (13)$$

As another of the colligative properties, the freezing point depression is directly related to the molality of the solution.

$$\Delta T_f = k_f m i_o \qquad (14)$$

where: k_f = the molal freezing point depression constant.

The value of k_f can be calculated for the solvent by:

$$k_f = -\frac{RT_o^2}{1000\ \ell_f} \qquad (15)$$

where: T_o = freezing point of pure solvent

R = ideal gas constant (1.987 cal/mol-deg)

ℓ_f = heat of fusion per gram (80. cal/g for water)

For water, the value of k_f is -1.86 deg/m.

Example 5. It was found that an aqueous solution of 10 g of a sugar dissolved in 50 g of water froze at -1.088°C. Calculate the molecular weight of the sugar.

a) T_o for water is 0°C, and T_s for the solution is -1.088°C. Then by Eq. (13)

$$\Delta T_f = (-1.088 - 0) = -1.088 .$$

b) Since $i_o = 1$ for non-electrolytes (all sugars) and $k_f = -1.86$ for water,

c) we have, combining Eqs. (14) and (15):

$$-1.088 = -1.86 \times \frac{10 \times 1000}{50 \times MW} \times 1 .$$

Solving for MW:

Ans. $MW = 342$ g/mol .

Problem 6. In winter, ethylene glycol, $C_2H_6O_2$, is added to the water in automobile radiators to keep them from freezing. Assuming the radiator holds 10 liters of water, how many liters of anti-freeze must be added to lower the freezing point of the solution to -10°F? You may assume the density of water to be 1.0 g/ml and that of the glycol 1.2 g/ml.

Problem 7. What must be the concentration of solutes in fish blood to keep it from freezing at -4°C?

Table 1 below offers a comparison of molecular constants for a number of common chemical solvents.

Table 1. MOLAL FREEZING POINT and BOILING POINT CONSTANTS

Solvent	Freezing Point (°C)	k_f	Boiling Point (°C)	k_b
Water	0.	- 1.86	100.	0.52
Acetic Acid	17.	- 3.90	118.	2.93
Benzene	5.5	- 5.10	80.1	2.53
Cyclohexane	6.5	-20.2	81.	2.79
Camphor	178.	-40.	208.	5.95

Problem 8. Suggest why the molecular weights of proteins are usually determined by freezing point depression and usually never by a boiling point elevation.

E. The Osmotic Pressure

The osmotic pressure is one of the most interesting of all the colligative properties. It is especially important since it is involved in very many biological processes. As the osmotic pressure is concerned with the passage of fluid through membranes, and since every cell and organ in living creatures is contained or surrounded by membranes, one can see how osmotic pressure is vital to the study of biological systems. A biological membrane is a layer of tissue composed of complex polymeric molecules, or proteins, which have the unique property of allowing only specific molecules or ions to pass through them, while all others are completely stopped. Some membranes act as though they were wire fences which might allow golf balls to pass through but not baseballs. Many synthetic membranes can be made which

limit the molecules which can pass through completely on a molecular weight basis. A medical application of this effect is the dialysis of blood of persons suffering from insufficient kidney action. Small molecules of urea and other toxins are removed while the larger hemoglobin molecules remain in the blood. Since the synthetic membrane is not as selective as the real kidney, the dialysis technique cannot be used as a permanent type treatment. The lung tissue, for example, can allow for the exchange of gases, oxygen and carbon dioxide, while the villi of the small intestine allow for the absorption of hydrolyzed proteins, fats, and water, from the digestion of food. These biological membranes are often referred to as "semi-permeable" although a better description of their action would be called "selectively permeable" since they can choose molecules to pass through based on their chemical properties and not only on their size. The passage of molecules through a membrane is called "osmosis".

In Figure 2 we see the effect of osmosis on a chemical system. An animal bladder permeable to water only is stretched across an inverted thistle tube and submerged in a beaker of pure water. A small amount of sugar solution is placed inside the thistle tube. Since water is the only substance that can pass through the membrane (and not the sugar), the water moves from the region of high chemical activity (pure water) to the region of lower chemical activity (sugar solution), i.e., in general, from lower concentration (of solute) to higher. Thus there is a net passage of water from the solvent into the thistle tube raising the level of solution in the tube. Since the driving force for the process is the equalization of the two concentrations, in theory, the process could continue for a very long time and drive a considerable amount of liquid into the tube. In practice the process stops either because the hydrostatic pressure developed in the tube due to the weight of the liquid becomes sufficient to prevent any more water from moving in, that is, an equilibrium situation results; or else the pressure may in all probability burst the membrane. What is so amazing is the enormous pressures which can be generated in this simple system. Since the entire process is reversible it is more convenient to define the osmotic pressure as the minimum pressure required to prevent osmosis from occurring across the membrane in the start position. When this is done it is discovered that an osmotic pressure of 22.4 atm, or the equivalent of 336 lb/in^2 is required to prevent osmosis into a one molal solution of a non-electrolyte. This pressure is capable of raising a column of water to a height of 760 feet! While the osmotic pressure does not appear on the simple phase diagram we have seen before, theory tells us that it results from an enormous amplification of the difference of vapor pressure between a solvent and a solution or between two

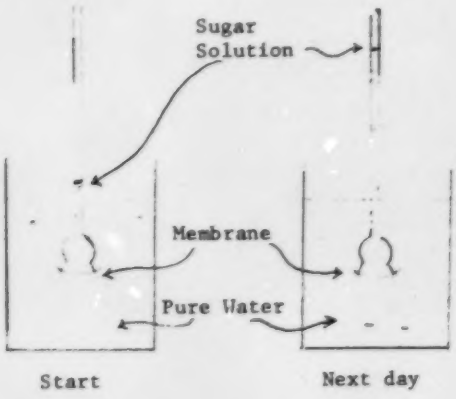


Figure 2. Osmosis.

solutions of differing concentrations. Therefore the osmotic pressure is included as one of the colligative properties of solutions. The equation for the osmotic pressure is:

Osmotic pressure: $\pi = RTmi_o$ (13)

where: π = osmotic pressure in atm
R = ideal gas constant (0.082059 liter-atm/mol-deg)
T = temperature (K)
m = molality (or molarity for dilute solutions)
i_o = Van't Hoff i factor

Since at 0°C the product of RT is exactly 22.4 and at 25°C it changes by only a few percent, occasionally the osmotic pressure equation is written:

$$\pi = 22.4\ mi_o$$

Example 3. Calculate the osmotic pressure produced by a 0.02 molar solution of calcium chloride, $CaCl_2$ at 25°C.

a) At 25°C the product RT is $0.082059 \times 298.1 = 24.5$
b) For $CaCl_2$ the i_o factor is 3, and using Eq. (13)

$$\pi = 24.5 \times 0.02 \times 3$$

Ans. $\pi = 1.47$ atm

Problem 9. What weight percent concentration of glucose, $C_6H_{12}O_6$, is required in the sap of trees to raise the sap to the top of a 100 foot tree at 25° 25°C? (1 atm is equivalent to approximately 34 feet of water)

F. Overview of Colligative Properties

It sould be apparent that there is a connection among the four colligative properties. This connection manifests itself first, through the physical consequences of the change of the chemical activity of the solvent as observed by the changes in the vapor pressure, and second, by the theoretical analysis which mathematically relates the four effects one to the other as seen by the listing below:

The Colligative Properties

1)	The Lowering of the Vapor Pressure	$\Delta P = X_2P_1^o$	(1)
2)	The Boiling Point Elevation	$\Delta T_b = k_bmi_o$	(8)
3)	The Freezing Point Depression	$\Delta T_f = k_fmi_o$	(14)
4)	The Osmotic Pressure	$\pi = RTmi_o$	(13)

SUMMARY

Upon completion of this module you will be ready to take a small quiz generated by the computer. Follow the instructions given you by your course advisor. If your work on the quiz is not satisfactory make sure to go over those parts of this module which cover that material.

G. Material for Advanced Work

1) Colligative properties can be used to study mixtures of two or more chemical substances. Each substance contributes its own share independent of the others so that the sum total becomes additive.

Example 4. Calculate the osmotic pressure of a solution at 25°C consisting of a solution which is 0.02 molal in $CuSO_4$ and 0.04 molal in Na_2SO_4.

$$\pi = RT(mi_o(CuSO_4) + mi_o(Na_2SO_4))$$
$$= 24.5(0.02(2) + 0.04(3))$$
$$\pi = 3.92 \text{ atm}$$

Problem 10. Calculate the freezing point of a solution of 20 g of methanol, CH_3OH, and an equal amount of ethylene glycol, $C_2H_6O_2$, in 100 g of water.

2) Colligative properties can be used to study dissociative effects of various solutes in solution through the determination of the Van't Hoff i factor. This is particularly important in the case of complex electrolytes or weak acids.

Example 5. A 0.2 molal solution of potassium ferricyanide, $K_3Fe(CN)_6$, in water boiled at 100.42°C. Write the dissociation equilibrium for the solute.

From the data: $\Delta T_b = 0.42$

From Eq. (8):

$$i_o = \frac{\Delta T_b}{k_b m}$$

Then:

$$i_o = \frac{0.42}{(0.52)(0.2)} = 4.04$$

Assuming: $i_o = 4$ (4 ions produced)

$$K_3Fe(CN)_6 \rightleftharpoons 3K^+ + Fe(CN)_6^{-3}$$

Problem 11. The freezing point of a 0.1 molal solution of a water solution of a complex cobalt ammonia chloride, $Co(NH_3)_4Cl_3$, was found to be -0.37°C. Write the dissociation equilibrium for this compound.

3) Studies in Ionization of Weak Electrolytes.

Weak electrolytes are substances which ionize less than 100% in water solutions. For the most part, weak electrolytes are found to be in the class of substances known as organic carboxylic acids of which acetic, $HC_2H_3O_2$, oxalic, $H_2C_2O_4$, and propionic acid, $HC_3H_5O_2$, are examples. Although these acids have more than one hydrogen atom, the number of hydrogen atoms which can dissociate are generally only one (monoprotic), or two (diprotic), or three (triprotic), and so on. The reason for this is that those hydrogens directly bonded to carbon atoms are usually attached so strongly that they cannot dissociate in water, while those attached to oxygen usually can.

If a monoprotic acid of general formula HA were to dissociate completely in water solution its Van't Hoff i factor would be 2, while if it did not dissociate

at all, its factor would be 1. Therefore, if a weak electrolyte dissociated say, 5, 10, or 15%, its Van't Hoff i factor would be somewhere between 1 and 2, and its exact value would give us the exact percent dissociation.

The ionization of a weak monoprotic acid can be expressed as follows:

$$HA \rightleftharpoons H^+ + A^-$$

At equilibrium the ionization constant, K, can be written,

$$K = \frac{[H^+][A^-]}{[HA]}$$

where the square brackets, [], refer to molar concentrations at equilibrium. If we put into solution exactly 1 mole of pure acid per liter of solution and 5% were to dissociate, then

$$[H^+] = 0.05(1) = 0.05 \text{ M}$$
$$[A^-] = 0.05(1) = 0.05 \text{ M}$$
$$[HA] = 1 - 0.05(1) = 0.95 \text{ M}$$

and $$K = \frac{(0.05)(0.05)}{(0.95)} = 2.6 \times 10^{-3} .$$

If we let: α = fraction dissociated = $\frac{[H^+]}{[HA]_{original}}$

then: 100α = % dissociation .

If C is the original concentration of undissociated acid, then

$$[H^+] = \alpha C$$
$$[A^-] = \alpha C$$
$$[HA] = C - \alpha C = C(1 - \alpha)$$

and $$K = \frac{\alpha^2 C}{(1 - \alpha)} .$$

The quantity α can be evaluated from the Van't Hoff i factor as follows:

$$\alpha = \frac{i - 1}{i_o - 1} \qquad (15)$$

where: i = experimentally observed value from colligative properties

i_o = theoretical value assuming 100% dissociation (monoprotic acid, $i_o = 2$, etc.)

Example 6. For a 0.3 molar solution of a monoprotic acid showing 5% dissociation, calculate the expected experimental i factor and the boiling point.

a) For this acid $i_o = 2$; using Eq. (15)

$$0.05 = \frac{i - 1}{2 - 1}$$

Ans. $i = 1.05$

b) $\Delta T_b = 0.52(0.3)(1.05) = 0.16$
Boiling Point = 100.16°C

Problem 12. Calculate the Van't Hoff i factor and the equilibrium constant of a 0.6 M solution of a monoprotic acid which freezes at -1.16°C.

Problem Set 1

1. A SOLUTION OF 7.080 G OF A NON-ELECTROLYTE IN 136 G OF WATER BOILS AT 100.2035 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. THE TWO LIQUIDS HEXANE AND OCTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 100.75 DEG C ARE 1207.43 AND 628.52 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 100.75 DEG C, IN WHICH THE MOLE FRACTION OF HEXANE IS 0.075?

3. HOW MANY GRAMS OF $BrCH_2CONH_2$ MUST BE ADDED TO 401.99 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.518 MM HG LESS THAN THAT OF PURE WATER AT 76 DEG C. THE VAPOR PRESSURE OF WATER AT 76 DEG C IS 308.4 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

4. A SOLUTION OF 4.180 G OF A CERTAIN NON-ELECTROLYTE IN 286 G OF WATER FREEZES AT -0.0538 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

Problem Set 2

1. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 5.340 G OF $C_2H_5ClO_2$ IN 309 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

2. THE TWO LIQUIDS HEPTANE AND OCTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 100.25 DEG C ARE 780.22 AND 623.92 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 100.25 DEG C, IN WHICH THE MOLE FRACTION OF HEPTANE IS 0.181?

3. HOW MANY GRAMS OF $C_{12}H_{22}O_{11}$ MUST BE ADDED TO 213.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.046 MM HG LESS THAN THAT OF PURE WATER AT 27 DEG C. THE VAPOR PRESSURE OF WATER AT 27 DEG C IS 31.2 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

4. HOW MANY GRAMS OF THE $C_{14}H_{23}NO_6$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.468 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 3

1. A SOLUTION OF 7.570 G OF A CERTAIN NON-ELECTROLYTE IN 401 G OF WATER FREEZES AT -0.0675 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

2. LIQUIDS BENZENE AND TOLUENE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE TOLUENE IS 623.43 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 2.997 MOLES OF TOLUENE AND 2.003 MOLES OF BENZENE. WHAT IS THE VAPOR PRESSURE OF PURE BENZENE AT THIS TEMPERATURE?

3. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 1.120 G OF $BrCH_2CONH_2$ IN 75 G OF WATER AT 14 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 14 DEG C IS 14.9 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 5.400 G OF $BrCH_2CONH_2$ IN 375 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 4

1. HOW MANY GRAMS OF THE $C_{14}H_{22}NO_6$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.177 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

2. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 3.030 G OF $CO(NH_2)_2$ IN 69 G OF WATER AT 54 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 54 DEG C IS 120.1 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

3. A SOLUTION OF 2.560 G OF A NON-ELECTROLYTE IN 184 G OF WATER BOILS AT 100.0474 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

4. LIQUIDS PENTANE AND HEXANE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE HEXANE IS 533.10 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 1.947 MOLES OF HEXANE AND 3.053 MOLES OF PENTANE. WHAT IS THE VAPOR PRESSURE OF PURE PENTANE AT THIS TEMPERATURE?

Problem Set 5

1. HOW MANY GRAMS OF $HCCH_2CONH_2$ MUST BE ADDED TO 412.99 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.111 MM HG LESS THAN THAT OF PURE WATER AT 41 DEG C. THE VAPOR PRESSURE OF WATER AT 41 DEG C IS 64.6 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

2. THE TWO LIQUIDS TOLUENE AND P-XYLENE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 139.13 DEG C ARE 981.88 AND 685.60 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 139.13 DEG C, IN WHICH THE MOLE FRACTION OF TOLUENE IS 0.246?

3. A SOLUTION OF 2.530 G OF A NON-ELECTROLYTE IN 496 G OF WATER BOILS AT 100.0279 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

4. A SOLUTION OF 8.910 G OF A CERTAIN NON-ELECTROLYTE IN 455 G OF WATER FREEZES AT -0.0680 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

Problem Set 6

1. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 7.350 G OF $C_6H_8O_7$ IN 53 G OF WATER AT 44 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 44 DEG C IS 74.9 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

2. THE TWO LIQUIDS HEPTANE AND OCTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 103.50 DEG C ARE 816.70 AND 654.16 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 103.50 DEG C, IN WHICH THE MOLE FRACTION OF HEPTANE IS 0.381?

3. HOW MANY GRAMS OF THE $HOCH_2CHO$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -2.840 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 0.710 G OF $BrCH_2CONH_2$ IN 471 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 7

1. HOW MANY GRAMS OF THE $C_6H_{10}O_5$ WOULD HAVE TO BE DISSOLVED IN 10[illegible] G OF WATER TO GIVE A SOLUTION FREEZING AT -0.924 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

2. HOW MANY GRAMS OF $C_6H_6C_3$ MUST BE ADDED TO 67.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 4.216 MM HG LESS THAN THAT OF PURE WATER AT 94 DEG C. THE VAPOR PRESSURE OF WATER AT 94 DEG C IS 613.3 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

3. LIQUIDS PENTANE AND HEPTANE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE HEPTANE IS 441.47 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 2.835 MOLES OF HEPTANE AND 2.165 MOLES OF PENTANE. WHAT IS THE VAPOR PRESSURE OF PURE PENTANE AT THIS TEMPERATURE?

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 1.160 G OF CH_3CSNH_2 IN 187 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 8

1. A SOLUTION OF 1.890 G OF A NON-ELECTROLYTE IN 123 G OF WATER BOILS AT 100.0504 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. THE VAPOR PRESSURE OF HEPTANE AND OCTANE AT 100.15 DEG C ARE 779.21 AND 623.08 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF HEPTANE IN A OCTANE SOLUTION WHICH BOILS AT 100.15 DEG C AT 760 MM HG?

3. A SOLUTION OF 5.700 G OF A CERTAIN NON-ELECTROLYTE IN 434 G OF WATER FREEZES AT -0.0573 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

4. HOW MANY GRAMS OF $HCCH_2CONH_2$ MUST BE ADDED TO 373.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.795 MM HG LESS THAN THAT OF PURE WATER AT 87 DEG C. THE VAPOR PRESSURE OF WATER AT 87 DEG C IS 473.3 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 9

1. HOW MANY GRAMS OF $C_{11}H_{20}O_{10}$ MUST BE ADDED TO 198.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.009 MM HG LESS THAN THAT OF PURE WATER AT 21 DEG C. THE VAPOR PRESSURE OF WATER AT 21 DEG C IS 22.4 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

2. THE VAPOR PRESSURE OF PENTANE AND HEXANE AT 40.42 DEG C ARE 818.65 AND 477.37 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF PENTANE IN A HEXANE SOLUTION WHICH BOILS AT 40.42 DEG C AT 760 MM HG?

3. HOW MANY GRAMS OF THE $HOCH_2CONH_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.889 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 4.960 G OF $C_7H_4ClO_2$ IN 25 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 10

1. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 8.260 G OF $ClCH_2CONH_2$ IN 408 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

2. LIQUIDS HEXANE AND CYCLOHEXANE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE CYCLOHEXANE IS 759.07 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 4.971 MOLES OF CYCLOHEXANE AND 0.029 MOLES OF HEXANE. WHAT IS THE VAPOR PRESSURE OF PURE HEXANE AT THIS TEMPERATURE?

3. HOW MANY GRAMS OF $C_8H_{10}C_2$ MUST BE ADDED TO 267.99 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.192 MM HG LESS THAN THAT OF PURE WATER AT 55 DEG C. THE VAPOR PRESSURE OF WATER AT 55 DEG C IS 125.7 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

4. HOW MANY GRAMS OF THE $C_6H_{12}C_6$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.956 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 11

1. THE VAPOR PRESSURE OF TOLUENE AND P-XYLENE AT 135.15 DEG C ARE 1044.55 AND 732.50 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF TOLUENE IN A P-XYLENE SOLUTION WHICH BOILS AT 135.15 DEG C AT 760 MM HG?

2. A SOLUTION OF 8.850 G OF A CERTAIN NON-ELECTROLYTE IN 140 G OF WATER FREEZES AT -0.2231 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

3. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 1.770 G OF $Cl_2CHCH(OH)_2$ IN 416 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

4. HOW MANY GRAMS OF $C_6H_8O_7$ MUST BE ADDED TO 45.00 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 3.812 MM HG LESS THAN THAT OF PURE WATER AT 64 DEG C. THE VAPOR PRESSURE OF WATER AT 64 DEG C IS 187.2 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 12

1. A SOLUTION OF 7.510 G OF A NON-ELECTROLYTE IN 316 G OF WATER BOILS AT 100.2026 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 7.840 G OF CH_3CSNH_2 IN 67 G OF WATER AT 52 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 52 DEG C IS 109.5 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

3. THE TWO LIQUIDS PENTANE AND HEPTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 74.61 DEG C ARE 1365.80 AND 528.39 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 74.61 DEG C, IN WHICH THE MOLE FRACTION OF PENTANE IS 0.539?

4. A SOLUTION OF 2.970 G OF A CERTAIN NON-ELECTROLYTE IN 302 G OF WATER FREEZES AT -0.0410 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

Problem Set 13

1. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 3.570 G OF $C_8H_{10}O_2$ IN 62 G OF WATER AT 72 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 72 DEG C IS 262.1 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

2. A SOLUTION OF 2.340 G OF A NON-ELECTROLYTE IN 357 G OF WATER BOILS AT 100.0568 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

3. HOW MANY GRAMS OF THE $C_7H_5ClO_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.873 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

4. THE VAPOR PRESSURE OF HEXANE AND CYCLOHEXANE AT 80.22 DEG C ARE 912.42 AND 752.30 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF HEXANE IN A CYCLOHEXANE SOLUTION WHICH BOILS AT 80.22 DEG C AT 760 MM HG?

Problem Set 14

1. A SOLUTION OF 1.860 G OF A NON-ELECTROLYTE IN 393 G OF WATER BOILS AT 100.0135 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. THE TWO LIQUIDS HEXANE AND OCTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 99.82 DEG C ARE 1193.10 AND 620.06 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 99.82 DEG C, IN WHICH THE MOLE FRACTION OF HEXANE IS 0.495?

3. A SOLUTION OF 0.850 G OF A CERTAIN NON-ELECTROLYTE IN 584 G OF WATER FREEZES AT -0.0072 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

4. HOW MANY GRAMS OF $C_7H_5ClO_2$ MUST BE ADDED TO 65.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 2.171 MM HG LESS THAN THAT OF PURE WATER AT 96 DEG C. THE VAPOR PRESSURE OF WATER AT 96 DEG C IS 659.3 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 15

1. A SOLUTION OF 4.310 G OF A CERTAIN NON-ELECTROLYTE IN 369 G OF WATER FREEZES AT -0.0749 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

2. A SOLUTION OF 8.600 G OF A NON-ELECTROLYTE IN 291 G OF WATER BOILS AT 100.1618 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

3. HOW MANY GRAMS OF $C_6H_{14}O_6$ MUST BE ADDED TO 169.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.259 MM HG LESS THAN THAT OF PURE WATER AT 37 DEG C. THE VAPOR PRESSURE OF WATER AT 37 DEG C IS 52.9 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

4. THE TWO LIQUIDS PENTANE AND HEXANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 59.90 DEG C ARE 1110.03 AND 668.29 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 59.90 DEG C, IN WHICH THE MOLE FRACTION OF PENTANE IS 0.148?

Problem Set 15

1. HOW MANY GRAMS OF THE $BrCH_2CONH_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -1.085 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

2. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 7.500 G OF $C_{12}H_{22}O_{11}$ IN 75 G OF WATER AT 79 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 79 DEG C IS 347.5 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

3. LIQUIDS TOLUENE AND P-XYLENE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE P-XYLENE IS 655.19 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 3.167 MOLES OF P-XYLENE AND 1.833 MOLES OF TOLUENE. WHAT IS THE VAPOR PRESSURE OF PURE TOLUENE AT THIS TEMPERATURE?

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 5.580 G OF $C_6H_{12}O_6$ IN 11 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 17

1. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 6.250 G OF $Cl_3CHCH(OH)_2$ IN 87 G OF WATER AT 90 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 90 DEG C IS 529.5 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

2. A SOLUTION OF 9.540 G OF A NON-ELECTROLYTE IN 130 G OF WATER BOILS AT 100.5005 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

3. A SOLUTION OF 4.470 G OF A CERTAIN NON-ELECTROLYTE IN 350 G OF WATER FREEZES AT -0.3770 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

4. LIQUIDS HEXANE AND CYCLOHEXANE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE CYCLOHEXANE IS 747.31 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 4.599 MOLES OF CYCLOHEXANE AND 0.401 MOLES OF HEXANE. WHAT IS THE VAPOR PRESSURE OF PURE HEXANE AT THIS TEMPERATURE?

Problem Set 18

1. A SOLUTION OF 8.030 G OF A NON-ELECTROLYTE IN 272 G OF WATER BOILS AT 100.0965 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. THE VAPOR PRESSURE OF HEPTANE AND OCTANE AT 103.63 DEG C ARE 818.18 AND 655.38 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF HEPTANE IN A OCTANE SOLUTION WHICH BOILS AT 103.63 DEG C AT 760 MM HG?

3. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 3.640 G OF $C_{11}H_{20}O_{10}$ IN 37 G OF WATER AT 97 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 97 DEG C IS 683.3 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

4. HOW MANY GRAMS OF THE $BrCH_2CONH_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -1.023 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

Problem Set 19

1. HOW MANY GRAMS OF TEE $C_{12}H_{22}C_{11}$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.461 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

2. LIQUIDS TOLUENE AND P-XYLENE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE P-XYLENE IS 633.02 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 2.718 MOLES OF P-XYLENE AND 2.282 MOLES OF TOLUENE. WHAT IS TEE VAPOR PRESSURE OF PURE TOLUENE AT THIS TEMPERATURE?

3. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 8.720 G OF $C_6H_8O_3$ IN 86 G OF WATER AT 59 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 59 DEG C IS 150.5 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

   A SOLUTION OF 2.460 G OF A NON-ELECTROLYTE IN 506 G OF WATER BOILS AT 100.0159 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

Problem Set 20

1. A SOLUTION OF 0.810 G OF A CERTAIN NON-ELECTROLYTE IN 117 G OF WATER FREEZES AT -0.0247 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

2. THE TWO LIQUIDS HEXANE AND CYCLOHEXANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 80.69 DEG C ARE 918.57 AND 756.89 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 80.69 DEG C, IN WHICH THE MOLE FRACTION OF HEXANE IS 0.500?

3. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 0.550 G OF $C_{10}H_8N_2$ IN 31 G OF WATER AT 6 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 6 DEG C IS 9.2 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 3.620 G OF $ClCH_2CONH_2$ IN 61 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

The CM Project

The Computer-enriched Module (CM) project is a collaborative effort by 19 faculty members in the disciplines of chemistry, mathematics and physics, to produce self-instructional computer-based materials at the introductory college level in those disciplines. Each module is designed to be usable in an academic environment with minimal computational facilities, and by students and faculty who are not programming experts. It may be used as an adjunct to standard textual materials, or in many cases, as a replacement for them. The primary aim of each module is to use the computer in such a way that students may take a more active role in the development and discovery of concepts and phenomena.

CM Project Staff

Chemistry	Mathematics	Physics
C. J. Jameson Chem. Group Leader U. of Ill. - CC Chicago, IL	J. H. Mayne Math. Group Leader Loyola University Chicago, IL	H. Weinstock Phys. Group Leader IIT Chicago, IL
M. Bader Moravian College Bethlehem, PA	R. A. Alo Carnegie-Mellon U. Pittsburgh, PA	D. Davidson Pima Comm. Coll. Tucson, AR
A. K. Jameson Loyola University Chicago, IL	N. C. Harbertson Cal. St. Univ. Fresno, CA	P. Goldstein Jersey City St. C. Jersey City, NJ
J. Manock Western Carolina U. Cullowhee, NC	L. C. Leinbach Gettysburg College Gettysburg, PA	W. Lang MacMurray College Jacksonville, IL
R. T. O'Neill Xavier University Cincinnati, OH	J. C. Mathews Iowa State Univ. Ames, IA	L. E. Turner, Jr. Pacific Union Coll. Angwin, CA
F. A. Settle, Jr. Va. Military Inst. Lexington, VA	L. E. Mauland U. of North Dakota Grand Forks, ND	S. L. Wiley Cal. State Univ. Dominguez Hills, CA
R. Williams (formerly) U. of Neb. Lincoln, NB		

Address all correspondence to

Professor H. Weinstock
Director, CM Project
Physics Department
Illinois Institute of Technology
Chicago, Illinois 60616

TEACHER'S GUIDE TO
A MODULE ON SOLUTIONS
UNIT 5. COLLIGATIVE PROPERTIES OF SOLUTIONS

MORRIS BADER

MORAVIAN COLLEGE

a computer-enriched module

for introductory chemistry

featuring the program

COLLIG

Supported by grants from the
National Science Foundation
Exxon Foundation

Copyright by CM Publications 1976
Illinois Institute of Technology

TEACHER'S GUIDE TO UNIT ON COLLIGATIVE PROPERTIES OF SOLUTIONS OF THE SOLUTIONS MODULE

EDUCATIONAL OBJECTIVES

Colligative properties are the backbone of many interesting and important chemical and biological systems. The effect of solutes on the equilibria between the solid, liquid, and vapor phases are introduced in a simple and logical development interspersed with numerous examples and problems. Many of the problems reflect "relevant" applications of colligative properties.

Depending on the background of the student in preparation for this module, a discussion of some advanced material is included. This material may be omitted without interfering with the objectives as outlined. Usually the Van't Hoff i factor is added as an ad-hoc assertion in many texts. In the present approach it is included as an integral part of the discussion throughout. The emphasis on units is still maintained and based on the C.G.S. system. The change to S.I. units is presently occurring in the more advanced courses but as this is written it has not trickled down to the more elementary courses.

IMPLEMENTATION

A discussion of phase equilibria is a necessary prerequisite to this unit. A unit on phase equilibria is available, for this purpose, in the module on gases, liquids and solids.

A quiz generating computer program has been written which can be used to test the student's comprehension of the material. The instructor has the capability of choosing: a) the number of quizzes to be generated, b) the number of questions per quiz, and c) the level of difficulty as a choice of QSET1 or QSET2 or both where the latter is somewhat the more difficult. The answers are printed with the exams in a batch mode system with all numbers and questions chosen by a random number generator. The question file and arrangement make it extremely easy to add, remove, or alter any question. There is a file of 10 organic and 11 inorganic compounds which could easily be enlarged.

ANSWERS TO PROBLEMS

1. $P_1 = X_1 P_1^\circ$

Let P_1 = 20 torr

P_1° = 23.8

Then $X_1 = 0.840$

Let N_1 = moles $H_2O = \frac{72}{18} = 4.0$

N_2 = moles glucose

$$0.840 = \frac{N_1}{N_1 + N_2} = \frac{4.0}{4.0 + N_2}$$

N_2 = 0.762 moles glucose

grams glucose = 0.762 moles × 180 g/mol

Ans. = 137.2 grams

2. $i_o = 5$ for $Al_2(SO_4)_3$

3. MW $CaCl_2$ = 111 g/mol

10% by wt $CaCl_2$ = 10 grams $CaCl_2$ per 90 g H_2O

i_o for $CaCl_2$ = 3

Effective moles of $CaCl_2 = \frac{10}{111} \times 3 = 0.27$

moles $H_2O = \frac{90}{18} = 5$

$$X_1 = \frac{5}{5 + 0.27} = 0.949$$

$P_1 = 0.949(23.8)$

Ans. = 22.6 torr

4. MW = 78

$T_o = 80.1 + 273.1 = 353.2$

$$k_b = \frac{(1.987)(353.2)^2}{1000 \times \frac{7417}{78}}$$

a) $k_b = 2.61$

b) $\Delta T_o = 84.54 - 80.1$

$\Delta T_b = 4.44$

Calculate MW of solute

$$m = \frac{4.44}{2.61} = 1.70$$

$$1.70 = \frac{20\ g \times 1000}{80 \times MW}$$

$$MW = 147\ g/mol$$

MW naphthalene = 128 g/mol
MW paradichlorobenzene = 147. g/mol
So unknown is probably paradichlorobenzene.

5. $\Delta T_b = 0.77°$

$MW = 115$

$0.77 = 0.52 m i_o$

$$m = \frac{23 \times 1000}{400 \times 115} = 0.5$$

$$i_o = \frac{0.77}{(0.52)(0.5)} = 2.96$$

Since $i_o = 3$

$(NH_4)H_2PO_4 \rightleftharpoons NH_4^+ + H^+ + HPO_4^-$

6. $°F = 1.8°C + 32$

$$°C = \frac{°F - 32}{1.8} = \frac{(-10)(-32)}{1.8}$$

$°C = -23.3°C$

Then $\Delta T_f = -23.3 = -1.86\ m(1)$
10 l H_2O + 10,000 g

$$m = \frac{23.3}{1.86} = 12.5$$

$$\text{Then } 12.5 = \frac{x\ g\ glycol \times 1000}{10{,}000 \times 62}$$

$x = 7{,}750$ g of ethylene glycol

$$Vol = \frac{mass}{density} = \frac{7{,}750\ g}{1.2\ g/ml} = 6458\ ml$$

Ans. = 6.46 liters

7. $\Delta T_f = -4$

$$m = \frac{4}{1.86} = 2.15$$

Ans. = 2.15 molal

8. The "white" of an egg is a typical animal protein. What happens when an egg is put in boiling water?

9. Hydrostatic Pressure in units of force/area,

P = height liquid × density × acceleration of gravity.

Then to find a height of water equivalent to 1 atm (76 cm of Hg)

$$76 \text{ cm of Hg} \times 13.6 \frac{g}{cm^3} = ? \text{ cm of } H_2O \times 1 \frac{g}{cm^3}$$

$$\text{In feet of water, height} = (76 \times 13.6) \text{ cm} \times \frac{1 \text{ in}}{2.54 \text{ cm}} \times \frac{1 \text{ ft}}{12 \text{ in}}$$

Then ht = 34 ft of water per atm

$$\pi = 100 \text{ ft} \times \frac{1 \text{ atm}}{34 \text{ ft}} = 2.94 \text{ atm}$$

$$\pi = 22.4 \text{ m } (1)$$

$$m = \frac{2.94}{2.24} = 0.131 \text{ molal}$$

Let Y = grams of glucose

$$0.131 = \frac{Y(1000)}{(100 - Y) \times 180}$$

Y = 2.30 g glucose per 100 g solution

% w/w glucose = 2.30%

10. moles of methanol $= \frac{20}{32} = 0.625$

moles of ethylene glycol $= \frac{20}{62} = 0.323$

molality of methanol $= \frac{0.625 \times 1000}{100} = 6.25$

molality of glycol $= \frac{0.323 \times 1000}{100} = 3.23$

$\Delta T_f = 1.86[6.25 + 3.23] = 17.63$

Ans. Freezing Point = -17.63°C

11. $\Delta T_f = 0.37$

$$i_o = \frac{\Delta T_f}{1.86\ m} = \frac{0.37}{(1.86)(0.1)} = 1.98$$

$i_o \simeq 2$

Ans. $Co(NH_3)_4Cl_3 \rightarrow Co(NH_3)_4Cl_2^+ + Cl^-$

12. A liter of a dilute solution has approximately 1000 grams of water. The molality of the solution is ≈0.6 m.

$\Delta T_f = 1.16$

$$i = \frac{\Delta T_f}{k_f m} = \frac{1.16}{(1.86)(0.6)}$$

$i = 1.04$

$$\alpha = \frac{1.04 - 1}{2 - 1} = 0.04$$

$$K_{eq} = \frac{\alpha^2 C}{1 - \alpha} = \frac{(0.04)^2(0.6)}{0.96}$$

Ans. $K_{eq} = 1 \times 10^{-3}$

11. $\Delta T_f = 0.37$

$$i_o = \frac{\Delta T_f}{1.86\ m} = \frac{0.37}{(1.86)(0.1)} = 1.98$$

$i_o \approx 2$

Ans. $Co(NH_3)_4Cl_3 \rightarrow Co(NH_3)_4Cl_2^+ + Cl^-$

12. $\Delta T_f = 1.16$

$$i = \frac{\Delta T_f}{k_f\ m} = \frac{1.16}{(1.86)(0.6)}$$

a) $i = 1.04$

b) $= \frac{1.04 - 1}{2 - 1} = 0.04$

$K_{eq} =$

Ans. $K_{eq} = 1 \times 10^{-3}$

ANSWERS TO PROBLEM SETS

TEST 1

1. 1.31E+02
2. 6.72E+02 MM HG
3. 5.18E+00
4. 5.05E+02

TEST 2

1. 100.0565
2. 6.52E+02 MM HG
3. 5.98E+00
4. 8.78E+00

TEST 3

1. 5.20E+02
2. 9.64E+02 TORR
3. 1.490E+01 TORR
4. 100.0534

TEST 4

1. 3.33E+00
2. 1.185E+02 TORR
3. 1.50E+02
4. 9.05E+02 TORR

TEST 5

1. 2.97E+00
2. 7.58E+02 MM HG
3. 9.35E+01
4. 5.36E+02

TEST 6

1. 7.347E+01 TORR
2. 7.16E+02 MM HG
3. 9.17E+00
4. 100.0056

TEST 7

1. 7.46E+00
2. 3.27E+00
3. 1.18E+03 TORR
4. 100.0423

TEST 8

1. 1.56E+02
2. 8.77E-01
3. 4.26E+02
4. 2.62E+00

TEST 9

1. 1.39E+00
2. 8.28E-01
3. 3.59E+00
4. 100.6488

TEST 10

1. 100.1108
2. 9.21E+02 TORR
3. 3.14E+00
4. 9.26E+00

TEST 11

1. 8.81E-02
2. 5.27E+02
3. 100.0166
4. 6.55E+00

TEST 12

1. 6.00E+01
2. 1.066E+02 TORR
3. 9.80E+02 MM HG
4. 4.46E+02

TEST 13

1. 2.602E+02 TORR
2. 5.91E+01
3. 7.35E+00
4. 4.81E-02

TEST 14

1. 1.79E+02
2. 9.04E+02 MM HG
3. 3.75E+02
4. 1.88E+00

TEST 15

1. 2.90E+02
2. 9.35E+01
3. 8.45E+00
4. 7.34E+02 MM HG

TEST 16

1. 9.10E+00
2. 3.457E+02 TORR
3. 9.41E+02 TORR
4. 101.4416

TEST 17

1. 5.244E+02 TORR
2. 7.51E+01
3. 6.30E+01
4. 9.06E+02 TORR

TEST 18

1. 1.57E+02
2. 6.43E-01
3. 6.795E+02 TORR
4. 7.59E+00

TEST 19

1. 8.48E+00

2. 9.11E+02 TORR

3. 1.483E+02 TORR

4. 1.56E+02

TEST 20

1. 5.22E+02

2. 8.38E+02 MM HG

3. 9.139E+00 TORR

4. 100.3249

SOFTWARE

The program is written in Standard Fortran IV as adapted for the IBM 1130 with an 8K core and line printer. The computer needs are therefore minimal. The output of the program is on a standard 50 line form and requires only 120 characters per line. The file system is particular to the IBM 1130, (DEFINE FILE Statement), for which there is a simple translation to other computers. The program does not make use of files to store individual student results as other programs are available to perform there record-keeping tasks.

Included in the program is an adaptation of a random number generator which can generate an integer value between any two given values. This program is written as a Function subprogram and will run on any machine with the one change of substituting the largest integer available, for the value 32,767 which appears in RANDS. The sorting program ISORT sorts the problems in the order as given in the program. The statement: CALL ISORT(NQS,JQS,1) may be omitted if desired. For the computer-phile ISORT is a very fast "bubble" sort routine. To add more chemical substances to the file, the value of 21 should be increased in the DEFINE FILE statement. The program prints the questions and answers on the same sheet with a common exam code and copy code. A dashed line is printed and the exams and answers may be separated by cutting on the line. A simple internal check keeps the computer from selecting the same question twice. The exam code acts as the initial random number generator in selecting an exam sequence. An initial off-line dialogue is shown in the example. This is written in an interactive manner on the computer console but the exams are printed on the high-speed printer. The BASIC version has a similar dialogue at the terminal and the exams are also printed at the terminal.

A Typical Generated Quiz of 5 Questions.

(FORTRAN version)

NAME EXAM 1111 COPY 11

DATE 3/20/75 SECTION

QUESTION 1
CALCULATE THE OSMOTIC PRESSURE OF A SOLUTION CONTAINING 23. GRAMS OF PROPYLENE GLYCOL, C3H8O2, IN 393. GRAMS OF WATER.

QUESTION 2
AN AQUEOUS SOLUTION FREEZES AT -0.83 DEGREES AND CONTAINS 7. GRAMS OF A NON-ELECTROLYTE IN 124. GRAMS OF WATER. CALCULATE THE MOLECULAR WEIGHT OF THE SOLUTE.

QUESTION 3
AN ORGANIC SOLUTE DISSOLVED IN BENZENE,(C6H6),DEPRESSED THE FREEZING POINT OF BENZENE 2.63 DEGREES. ANALYSIS OF THE SOLUTION SHOWED THAT IT CONTAINED 14. GRAMS OF SOLUTE IN 208. GRAMS OF BENZENE.
THE FREEZING POINT OF BENZENE IS 5.5 DEG. C. AND THE DEPRESSION CONSTANT IS 4.90 DEG/M. CALCULATE THE MOLECULAR WEIGHT OF THE SOLUTE.

QUESTION 4
AN AQUEOUS SOLUTION CONTAINS 5. GRAMS OF CALCIUM CHLORIDE, CACL2, AND BOILS AT 100.76 DEGREES. HOW MANY GRAMS OF WATER ARE IN THIS SOLUTION.

QUESTION 5
CALCULATE THE BOILING POINT OF A SOLUTION OF 5. GRAMSOF IODOFORM,(CHI3),IN 37. GRAMS OF BENZENE,(C6H6). THE BOILING POINT OF BENZENE IS 80. DEG. C. AND THE BOILING POINT CONSTANT IS 2.53 DEG/M.(A.WT. C=12,H=1,I=127)

The Answer Sheet and Initial Off-Line Dialogue

(FORTRAN version)

```
ENTER MONTH,DAY,AND YEAR. (3I2)
32075
DO YOU WANT QUESTIONS FROM SET 1,SET 2, BOTH, OR EXIT.
 ENTER 1 = SET 1, 2 = SET 2, 3 = BOTH, 4 = EXIT.
1
HOW MANY EXAMS DO YOU WANT PRINTED. (I3)
30
HOW MANY QUESTIONS PER EXAM. (I2)
5
ENTER AN EXAM CODE NUMBER FROM 1000 TO 9999.
1111
```

```
+----------------------------------+

  EXAM 1111      COPY  11

  DATE   4/13/75



  QUES.  1
  OSMOTIC PRESS. =
     17.24 ATM.



  QUES.  2
  MOL.WT. =    126.00



  QUES.  3
  MOL.WT. =    125.00

  QUES.  4
     92.00 GRAMS.

  QUES.  5
  B.P. =     80.86 DEG.C.

+----------------------------------+
```

Mainline for Quiz Generating Program

(FORTRAN version)

```
// JOB
// FOR
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
*IOCS(CARD,1132PRINTER,DISK,KEYBOARD,TYPEWRITER)
      REAL MWA(10),MWB(11)
      COMMON IX,IY,IQS
      COMMON LISTA(10,15),LISTB(11,15),PCT(10,3),IONB(11),JQS(20)
      COMMON MWA,MWB,CF,CB,CP,NQS,K
      DEFINE FILE 3(21,24,U,IAB)
C.....THIS CALCULATES THE VAPOR PRESSURE OF WATER IN TORR.
      VPW(T)=7.239E+8*EXP(-5136.39/(T+273.15))
C.....CON CALCULATES THE MOLALITY OF A SOLUTION.
      CON(SU,SO,W)=1000.*SU/(SO*W)
C.....CF AND CB ARE THE FREEZING AND BOILING POINT CONSTANTS FOR WATER.
      CF=-1.86
      CB=0.52
      CP=22.4
C.....LISTA CONSISTS OF 10 ORGANIC SUBSTANCES.
C.....LISTB CONSISTS OF 11 INORGANIC SUBSTANCES.
      K=0
      DO 3 I=1,10
      K=K+1
      READ(3'K)(LISTA(K,J),J=1,15),MWA(K),IN,(PCT(K,J),J=1,3)
3     CONTINUE
      DO 6 I=1,11
      K=K+1
      READ(3'K)(LISTB(I,J),J=1,15),MWB(I),IONB(I)
6     CONTINUE
      WRITE(1,14)
14    FORMAT(' ENTER MONTH,DAY,AND YEAR. (3I2)')
      READ(6,15)MO,ID,JY
15    FORMAT(3I2)
42    WRITE(1,41)
41    FORMAT(' DO YOU WANT QUESTIONS FROM SET 1,SET 2, BOTH, OR EXIT.'//
     1' ENTER 1 = SET 1, 2 = SET 2, 3 = BOTH, 4 = EXIT.')
      READ(6,5)L
5     FORMAT(I1)
      IF(L)44,44,43
43    IF(L-4)53,53,44
44    WRITE(1,45)
45    FORMAT(' INPUT NOT CLEAR.')
      GO TO 42

53    GO TO(46,47,48,99),L
46    NL=1
      NH=10
      GO TO 49
47    NL=11
      NH=20
      GO TO 49
48    NL=1
      NH=20
49    WRITE(1,10)
10    FORMAT(' HOW MANY EXAMS DO YOU WANT PRINTED.  (I3)')
      READ(6,11)NXM
11    FORMAT(I3)
```

```
      WRITE(1,12)
12    FORMAT(' HOW MANY QUESTIONS PER EXAM.  (I2)')
      READ(6,15)NQS
      WRITE(1,16)
16    FORMAT(' ENTER AN EXAM CODE NUMBER FROM 1000 TO 9999.')
      READ(6,17)ICODE
17    FORMAT(I4)
      IX=ICODE
      DO 30 JCPY=1,NXM
      DO 2 I=1,20
2     JQS(I)=999
      DO 19 I=1,NQS
18    NUM=RNDX(NL,NH)
      DO 20 J=1,NQS
      IF(JQS(J)-NUM)20,18,20
20    CONTINUE
      JQS(I)=NUM
19    CONTINUE
      CALL ISORT(NQS,JQS,1)
      WRITE(3,22)
22    FORMAT(1H1)
      WRITE(3,23)
23    FORMAT(1X,120('-'))
      WRITE(3,25)
25    FORMAT(1H+,T2'I',T85'I',T121'I'/)
      WRITE(3,27)ICODE,JCPY,ICODE,JCPY,MO,ID,JY,MO,ID,JY
27    FORMAT(T5'NAME'T50'EXAM'I5,T63'COPY'I4,T90'EXAM'I5,T105'COPY'I4//
     1T5'DATE'I4'/'I2'/'I2,T50'SECTION'T90'DATE'I4'/'I2'/'I2)
      DO 40 IQS=1,NQS
      K=JQS(IQS)
      WRITE(3,28)IQS
28    FORMAT(//T5'QUESTION'I4,T85'I')
      IF(K-10)32,32,33
32    CALL QSET1
      GO TO 40
33    K=K-10
      CALL QSET2
40    CONTINUE
      WRITE(3,50)
50    FORMAT(///)
      WRITE(3,23)
      WRITE(3,25)
30    CONTINUE
      GO TO 42
99    CALL EXIT
      END


// XEQ FXAM1     2
*FILES(3,CMPD)
*LOCALEXAM1,QSET1,QSET2
```

The Routine Problem Set - QSET 1

```
// FOR
*ONE WORD INTEGERS                                    (FORTRAN version)
      SUBROUTINE QSET1
      REAL MWA(10),MWB(11)
      COMMON IX,IY,IQS
      COMMON LISTA(10,15),LISTB(11,15),PCT(10,3),IONB(11),JQS(20)
      COMMON MWA,MWB,CF,CB,CP,NQS,K
C.....THIS CALCULATES THE VAPOR PRESSURE OF WATER IN TORR.
      VPW(T)=7.239E+8*EXP(-5136.39/(T+273.15))
C.....CON CALCULATES THE MOLALITY OF A SOLUTION.
      CON(SU,SO,W)=1000.*SU/(SO*W)
C.....CF AND CB ARE THE FREEZING AND BOILING POINT CONSTANTS FOR WATER.
      GO TO(51,52,53,54,55,56,57,58,59,60),K
51    G=RNDX(2,20)
      L=RNDX(1,10)
      W=RNDX(100,250)
      WRITE(3,151)G,(LISTA(L,M),M=1,15),W
151   FORMAT(T5'CALCULATE, (A), THE FREEZING POINT AND (B), THE BOILING
     1POINT OF A '/T5'SOLUTION OF'F4.0' GRAMS OF '15A2' PER'F6.0' GRAMS
     2'/T5'OF WATER.')
      R=CON(G,W,MWA(L))
      TF=CF*R
      TB=100.+CB*R
      CALL QUES
      WRITE(3,251)TF,TB
251   FORMAT(T90'(A) F.P. = 'F8.2/T90'(B) B.P. = 'F8.2)
      GO TO 40
52    G=RNDX(10,15)
      L=RNDX(1,11)
      W=RNDX(300,350)
      WRITE(3,152)G,(LISTB(L,M),M=1,15),W
152   FORMAT(T5'CALCULATE (A) THE FREEZING POINT AND (B) THE BOILING POI
     1NT OF A '/T5'SOLUTION CONTAINING'F4.0' GRAMS OF '15A2'DISSOLVED'/
     2T5'IN'F5.0 ' GRAMS OF WATER.')
      R=CON(G,W,MWB(L))*IONB(L)
      FP=CF*R
      BP=100.+CB*R
      CALL QUES
      WRITE(3,251)FP,BP
      GO TO 40
53    G=RNDX(10,30)
      L=RNDX(1,10)
      W=RNDX(250,600)
      WRITE(3,153)G,(LISTA(L,M),M=1,15),W
153   FORMAT(T5'CALCULATE THE OSMOTIC PRESSURE OF A SOLUTION CONTAINING'
     1F4.0' GRAMS OF '/T5,15A2,'IN 'F6.0' GRAMS OF WATER.')
      R=CON(G,W,MWA(L))
      PR=CP*R
      CALL QUES
      WRITE(3,253)PR
253   FORMAT(T90'OSMOTIC PRESS. ='/T90,F8.2' ATM.')
      GO TO 40
54    ANS=RNDX(60,150)
      G=RNDX(5,15)
      W=RNDX(100,300)
      T=CON(G,W,ANS)*CF
      WRITE(3,154)T,G,W
154   FORMAT(T5'AN AQUEOUS SOLUTION FREEZES AT'F6.2' DEGREES  AND'/T5'CO
     1NTAINS'F4.0' GRAMS OF A NON-ELECTROLYTE IN'F6.0' GRAMS OF WATER.'/
```

```
     2T5'CALCULATE THE MOLECULAR WEIGHT OF THE SOLUTE.')
      CALL QUES
      WRITE(3,254)ANS
254   FORMAT(T90'MOL.WT. = 'F8.2)
      GO TO 40
55    ANS=RNDX(60,200)
      G=RNDX(10,30)
      W=RNDX(150,250)
      T=4.9*CON(G,W,ANS)
      WRITE(3,155)T,G,W
155   FORMAT(T5'AN ORGANIC SOLUTE DISSOLVED IN BENZENE,(C6H6),DEPRESSED
     1THE FREEZING'/T5'POINT OF BENZENE'F6.2' DEGREES. ANALYSIS OF THE S
     2OLUTION SHOWED THAT IT'/T5'CONTAINED'F5.0' GRAMS OF SOLUTE IN'F5.0
     3' GRAMS OF BENZENE.'/T5'THE FREEZING POINT OF BENZENE IS 5.5 DEG.
     4C. AND THE DEPRESSION CONSTANT'/T5'IS 4.90 DEG/M. CALCULATE THE MO
     5LECULAR WEIGHT OF THE SOLUTE.')
      CALL QUES
      WRITE(3,254)ANS
      GO TO 40
56    G=RNDX(5,10)
      L=RNDX(1,11)
      ANS=RNDX(50,150)
      T=100.+CB*CON(G,ANS,MWB(L))*IONB(L)
      WRITE(3,156)G,(LISTB(L,J),J=1,15),T
156   FORMAT(T5'AN AQUEOUS SOLUTION CONTAINS'F4.0' GRAMS OF '15A2'AND'/
     1T5'BOILS AT'F7.2' DEGREES. HOW MANY GRAMS OF WATER ARE IN THIS SOL
     2UTION.')
      CALL QUES
      WRITE(3,256)ANS
256   FORMAT(T90,F8.2' GRAMS.')
      GO TO 40
57    G=RNDX(1,3)
      L=RNDX(1,10)
      ANS = RNDX(1,4)*MWA(L)
      T=5.5-4.9*1000.*G/ANS
      WRITE(3,157)G,(LISTA(L,J),J=1,15),T
157   FORMAT(T5'A SOLUTION CONTAINS'F3.0' MOLES OF '15A2' DISSOLVED'/T5'
     1IN BENZENE,(C6H6),AND FREEZES AT'F8.2' DEGREES. HOW MANY GRAMS OF
     2BENZENE'/T5'DOES THIS SOLUTION CONTAIN. THE FREEZING POINT OF BENZ
     3ENE IS 5.5 DEG.'/T5'AND THE FREEZING POINT CONSTANT IS 4.90 DEG/M.
     4')
      CALL QUES
      WRITE(3,256)ANS
      GO TO 40
58    T=RNDX(40,80)
      VP=VPW(T)
      G=RNDX(100,150)
      L=RNDX(1,10)
      W=RNDX(500,800)
      PR=(W/18.)/(W/18.+G/MWA(L))*VP
      WRITE(3,158)G,(LISTA(L,J),J=1,15),W,T,VP
158   FORMAT(T5'CALCULATE THE VAPOR PRESSURE OF WATER ABOVE A SOLUTION C
     1ONTAINING'/T5,F5.0' GRAMS OF '15A2'IN'F5.0' GRAMS OF WATER'/T5'AT'
     2F4.0' DEGREES. THE VAPOR PRESSURE OF PURE WATER AT THIS TEMPERATUR
     3E'/T5'IS'F7.2' TORR.')
```

```
      CALL QUES
      WRITE(3,258)PR
258   FORMAT(T90,F8.2' TORR')
      GO TO 40
59    G=RNDX(5,10)
      W=RNDX(20,50)
      WT=394.
      T=80.+2.53*CON(G,W,WT)
      WRITE(3,159)G,W
159   FORMAT(T5'CALCULATE THE BOILING POINT OF A SOLUTION OF'F4.0' GRAMS
     1OF IODOFORM,(CHI3),IN'/T5,F4.0' GRAMS OF BENZENE,(C6H6). THE BOILI
     2NG POINT OF BENZENE IS 80. DEG. C.'/T5'AND THE BOILING POINT CONST
     3ANT IS 2.53 DEG/M.(A.WT. C=12,H=1,I=127)')
      CALL QUES
      WRITE(3,259)T
259   FORMAT(T90'B.P. = 'F8.2' DEG.C.')
      GO TO 40
60    ANS=RNDX(60,150)
      G=RNDX(10,20)
      W=RNDX(100,200)
      C=22.4*76.*CON(G,W,ANS)
      WRITE(3,160)C,G,W
160   FORMAT(T5'CALCULATE THE MOLECULAR WEIGHT OF A NON-ELECTROLYTE WHIC
     1H PRODUCES'/T5'AN OSMOTIC PRESSURE OF'F7.0' CM OF HG WHEN'F4.0' GR
     2AMS'/T5' ARE DISSOLVED IN'F5.0' GRAMS OF WATER.')
      CALL QUES
      WRITE(3,254)ANS
40    RETURN
      END
```

The More Difficult Problem Set - QSET 2

(FORTRAN version)

```
// FOR
*ONE WORD INTEGERS
      SUBROUTINE QSET2
      REAL MWA(10),MWB(11)
      COMMON IX,IY,IQS
      COMMON LISTA(10,15),LISTB(11,15),PCT(10,3),IONB(11),JQS(20)
      COMMON MWA,MWB,CF,CB,CP,NQS,K
C.....THIS CALCULATES THE VAPOR PRESSURE OF WATER IN TORR.
      VPW(T)=7.239E+8*EXP(-5136.39/(T+273.15))
C.....CON CALCULATES THE MOLALITY OF A SOLUTION.
      CON(SU,SO,W)=1000.*SU/(SO*W)
C.....CF AND CB ARE THE FREEZING AND BOILING POINT CONSTANTS FOR WATER.
      GO TO (61,62,63,64,65,66,67,68,69,70),K
61    L=RNDX(1,11)
      T=RNDX(40,80)
      VP=VPW(T)
      W=RNDX(100,200)
      ANS=RNDX(20,75)
      F1=W/18.
      F2=ANS*IONB(L)/MWB(L)
      F=F1*VP/(F1+F2)
      WRITE(3,161)(LISTB(L,J),J=1,15),W,T,F,VP
```

```
161   FORMAT(T5'HOW MANY GRAMS OF '15A2'MUST BE ADDED TO'F5.0' GRAMS'/T5
     1'OF WATER AT 'F4.0' DEG C TO LOWER THE VAPOR PRESSURE OF WATER TO'
     2F6.2' TORR.'/T5'THE VAPOR PRESSURE OF WATER AT THIS TEMPERATURE IS
     3'F7.2' TORR.')
      CALL QUES
      WRITE(3,261)ANS
261   FORMAT(T90,F8.2' GRAMS.')
      GO TO 40
62    G=RNDX(5,10)
      W=RNDX(100,200)
      ANS=67000.+1000.*RNDX(1,10)
      T=CP*760.*CON(G,W,ANS)
      WRITE(3,162)G,W,T
162   FORMAT(T5'THE OSMOTIC PRESSURE OF A SOLUTION OF'F4.0' GRAMS OF HEM
     1OGLOBIN'/T5'DISSOLVED IN'F5.0' GRAMS OF WATER IS'F4.0' TORR AT'/
     2T5'25 DEG C. ESTIMATE THE MOLECULAR WEIGHT OF HEMOGLOBIN.')
      CALL QUES
      WRITE(3,262)ANS
262   FORMAT(T90'M.W. = 'F9.2)
      GO TO 40
63    L=RNDX(1,11)
      T=RNDX(40,80)
      GA=RNDX(40,70)
      WA=RNDX(300,500)
      GB=RNDX(71,100)
      WB=RNDX(300,500)
      VP=VPW(T)
      Y=GB*(WA+WB)/(GA+GB)
      SOLB=GB+Y
      SOLA=GA+WA+WB-Y
      F1=Y/18.
      F2=GB*IONB(L)/MWB(L)
      PR=F1*VP/(F1+F2)
      WRITE(3,163)(LISTB(L,J),J=1,15),T,GA,WA,GB,WB
163   FORMAT(T5'TWO BEAKERS LABELED A AND B, BOTH CONTAINING SOLUTIONS O
     1F'/T5,15A2,'IN WATER ARE PLACED IN AN EVACUATED BELL-JAR'/T5'AT'F5
     2.0' DEG. C. AND ALLOWED TO EQUILIBRATE. INITIALLY A CONTAINS'/T5,F
     35.0' GRAMS OF SOLUTE IN'F5.0' GRAMS OF WATER.'/T5'AND B CONTAINS'
     4F5.0' GRAMS OF SOLUTE IN'F5.0' GRAMS OF WATER. CALCULATE'/T5'(A) T
     5HE WEIGHT OF EACH SOLUTION AT EQUILIBRIUM AND')
      WRITE(3,363)VP
363   FORMAT(T5'(B) THE VAPOR PRESSURE OF WATER IN THE BELL/JAR.'/T5'THE
     1 VAPOR PRESSURE OF PURE WATER AT THIS TEMPERATURE IS'F6.1' TORR.')
      CALL QUES
      WRITE(3,263)SOLA,SOLB,PR
263   FORMAT(T90'SOL.A = 'F6.2' GRAMS.'/T90'SOL.B = 'F6.2' GRAMS.'/T90
     1'V.P. = 'F6.2' TORR')
      GO TO 40
64    ANS=RNDX(5,15)
      G=RNDX(1,5)/999.99
      W=RNDX(100,300)
      PR=76.*CP*G*ANS*1000./W
      WRITE(3,164)G,W,PR
164   FORMAT(T5'AN UNKNOWN POLYSACCHARIDE IS KNOWN TO HYDROLYZE IN ACID
     1SOLUTION TO SIMPLE'/T5'SUGARS (GLUCOSE UNITS) OF FORMULA C6H1206.
     2WHEN'F7.4' MOLES OF THE'/T5'POLYSACCHARIDE WAS DISSOLVED IN'F5.0'
```

```
     3GRAMS OF WATER AT 25 DEG C. IT WAS FOUND'/T5'TO PRODUCE AN OSMOTIC
     4 PRESSURE OF'F8.2' CM OF HG. CALCULATE THE NUMBER OF'/T5'GLUCOSE U
     5NITS CONTAINED IN THE POLYSACCHARIDE.')
      CALL QUES
      WRITE(3,264)ANS
264   FORMAT(T90,F4.0' GLUCOSE UNITS.')
      GO TO 40
65    L=RNDX(1,5)
      G=RNDX(5,10)
      W=RNDX(10,20)
      WS=RNDX(200,400)
      KQ=RNDX(1,2)
      GO TO(71,72),KQ
71    L2=RNDX(6,10)
      R=CON(G,WS,MWA(L))+CON(W,WS,MWA(L2))
      FP=CF*R
      BP=CB*R
      WRITE(3,165)G,(LISTA(L,J),J=1,15),W,(LISTA(L2,J),J=1,15),WS
165   FORMAT(T5'A SOLUTION CONTAINS'F4.0' GRAMS OF '15A2'AND'F4.0/T5'GRA
     1MS OF '15A2'IN'F5.0' GRAMS OF WATER. CALCULATE'/T5'(A) THE FREEZIN
     2G POINT AND (B) THE BOILING POINT OF THIS SOLUTION.'/T5'ASSUME THE
     3 EFFECT OF EACH SOLUTE IS ADDITIVE.')
      GO TO 73
72    L2=RNDX(6,11)
      WRITE(3,165)G,(LISTB(L,J),J=1,15),W,(LISTB(L2,J),J=1,15),WS
      R=CON(G,WS,MWB(L))*IONB(L)+CON(W,WS,MWB(L2))*IONB(L2)
      FP=CF*R
      BP=CB*R
73    CALL QUES
      WRITE(3,265)FP,BP
265   FORMAT(T90'(A) F.P. = 'F8.2/T90'(B) B.P. = 'F8.2)
      GO TO 40
66    L=RNDX(1,10)
      G=RNDX(5,30)
      W=RNDX(200,300)
      WT=MWA(L)
      TF=CF*CON(G,W,WT)
      WRITE(3,166)(PCT(L,M),M=1,3),G,W,TF
166   FORMAT(T5'A COMPOUND CONTAINS'F5.1' PERCENT CARBON,'F5.1' PERCENT
     1HYDROGEN, AND'F5.1/T5'PERCENT OXYGEN.'F5.0' GRAMS OF THIS SUBSTANC
     2F DISSOLVED IN'F5.0' GRAMS'/T5'OF WATER WILL FREEZE AT'F6.2' DEG.
     3C.  WHAT IS THE MOLECULAR'/T5'FORMULA OF THE COMPOUND IF IT IS A N
     4ON-ELECTROLYTE.')
      CALL QUES
      WRITE(3,266)(LISTA(L,M),M=1,12)
266   FORMAT(T90,12A2)
      GO TO 40
67    C=RNDX(1,100)/99.999
      ALPHA=RNDX(1,4)/99.999
      PCENT=100.*ALPHA/C
      CONST=C*ALPHA**2/(1.-ALPHA)
      TB=100.+CB*C*(1.+ALPHA)
      WRITE(3,167)C,TB
167   FORMAT(T5'A'F5.2' MOLAR SOLUTION OF A WEAK MONOPROTIC ACID BOILED
     1AT'F7.2' DEG. C.'/T5'CALCULATE (A) THE PERCENT IONIZATION OF THE A
```

```
     2CID AND (B) THE IONIZATION'/T5'CONSTANT FOR THE ACID.')
      CALL QUES
      WRITE(3,267)PCENT,CONST
267   FORMAT(T90'PERCENT = 'F6.2/T90'KEQ. = 'E11.3)
      GO TO 40
68    G=RNDX(2,15)/9.999
      W=RNDX(500,800)
      ALPHA=SQRT(1.8E-5*C)
      TB=100.+CB*G*1000./W*(1.+ALPHA)
      WRITE(3,168)G,W
168   FORMAT(T5'THE IONIZATION CONSTANT, K, FOR ACETIC ACID,HC2H3O2,IS'/
     1T5'1.8 E-5. CALCULATE THE BOILING POINT OF A SOLUTION COMPOSED OF'
     2F4.1' MOLES OF'/T5'ACID IN'F5.0' ML. OF SOLUTION.')
      CALL QUES
      WRITE(3,268)TB
268   FORMAT(T90'B.P. = 'F6.2' DEG.C.')
      GO TO 40
69    C1=RNDX(10,20)/99.999
      C2=RNDX(1,5)/99.999
      WRITE(3,169)C1,C2
169   FORMAT(T5'IF OSMOSIS IS RESPONSIBLE FOR SAP RISING IN A TREE, ESTI
     1MATE THE HEIGHT IN FEET'/T5'TO WHICH SAP CAN RISE AT 25 DEG. C. IF
     2 THE SAP IS'F5.2' MOLAR IN SUGAR, C6H12O6'  /T5'AND THE WATER OUTS
     3IDE THE SAP-BEARING TUBULE CONTAINS'/T5'NON-ELECTROLYTE  AT A CONC
     4ENTRATION OF'F5.2' MOLAR. NOTE THAT 1.0 CM OF HG'/T5'EXERTS THE SA
     5ME PRESSURE AS 13.6 CM OF WATER.')
      HT=CP*76.*13.6*(C1-C2)/(12.*2.54)
      CALL QUES
      WRITE(3,269)HT
269   FORMAT(T90,F8.2' FEET')
      GO TO 40
70    PH=RNDX(20,50)
      PG=100.-PH
      WS=RNDX(2,5)
      W=RNDX(10,50)
      WTH=PH*WS/100.
      WTG=PG*WS/100.
      RG=180.
      RH=423.
      TCON=CON(WTH,W,RH)+CON(WTG,W,RG)
      TF=CF*TCON
      WRITE(3,170)WS,W,TF
170   FORMAT(T5'''STREET'' HEROIN (MW=423) IS SOLD IMPURE MIXED WITH GLU
     1COSE,'/T5'C6H12O6 (MW=180). WHEN'F4.0' GRAMS OF IMPURE SAMPLE WAS
     2MIXED WITH'/T5,F4.0' GRAMS OF WATER THE SOLUTION FROZE AT'F7.2' DE
     3G. C.'/T5'ESTIMATE THE WEIGHT PERCENT OF HEROIN IN THE SAMPLE.')
      CALL QUES
      WRITE(3,270)PH
270   FORMAT(T90'PERCT HEROIN = 'F6.2)
40    RETURN
      END
// FOR
*ONE WORD INTEGERS
*LIST SOURCE PROGRAM
      SUBROUTINE QUES
      COMMON IX,IY,IQS
      WRITE(3,1)IQS
1     FORMAT(T85'I',I3,T90'QUES.'I3)
      RETURN
      END
```

Files Program to Store Some Basic Chemical Data
(FORTRAN version)

```
// DUP
*STOREDATA  WS  UA  CMPD     2
// FOR
*ONE WORD INTEGERS
*LIST SOURCE PROGRAM
*IOCS(CARD,1132PRINTER,DISK,KEYBOARD,TYPEWRITER)
      REAL MW
      DIMENSION LIST(15),PCT(3)
      DEFINE FILE 3(21,24,U,IA)
      K=0
      READ(2,11)N
      DO 6 I=1,N
      K=K+1
      READ(2,3)LIST,MW,ION,PCT
3     FORMAT(15A2,F5.0,I5,3F10.0)
      WRITE(3,8)LIST,MW,ION,PCT
8     FORMAT(1X,15A2,F10.2,I10,3F10.2)
      WRITE(3'K)LIST,MW,ION,PCT
6     CONTINUE
      READ(2,11)N
      DO 10 I=1,N
      K=K+1
      READ(2,3)LIST,MW,ION
      WRITE(3,8)LIST,MW,ION
      WRITE(3'K)LIST,MW,ION,PCT
10    CONTINUE
11    FORMAT(I2)
      CALL EXIT
      END
// XEQ          1
*FILES(3,CMPD)
10
ETHYLENE GLYCOL, C2H6O2,          62     38.7     9.7      51.6
ALCOHOL,  C2H5OH,                 46     52.2     13.      34.8
SUGAR, C12H22O11,                342     42.1     6.4      51.5
METHANOL, CH3OH,                  32     37.5     12.5     50.
GLYCERINE, C3H8O3,                92     39.1     8.7      52.2
PROPYLENE GLYCOL, C3H8O2,         76     47.4     10.5     42.1

ACETALDEHYDE, C2H4O,              44     54.5     9.1      36.4
GLUCOSE, C6H12O6,                180     40.      6.7      53.3
ISOPROPYL ALCOHOL, C3H8O,         60     60.      13.3     26.7
ACETONE, C3H6O,                   58     62.1     10.3     27.6
11
AMMONIUM PHOSPHATE, (NH4)3PO4, 149.    4
ALUMINUM ACETATE, AL(C2H3O2)3,204.     4
FERRIC SULFATE, FE2(SO4)3,      400    5
POTASSIUM OXALATE,  K2C2O4,   166.2    3
FERROUS BROMIDE, FEBR2,       215.7    3
NICKEL CHLORIDE, NICL2,       127.6    3
ALUMINUM CHLORIDE, ALCL3,     133.3    4
ZINC SULFATE, ZNSO4,          161.5    2
CALCIUM CHLORIDE, CACL2,        111    3
SODIUM PHOSPHATE, NA3PO4,       164    4
MAGNESIUM PHOSPHATE,MG3(PO4)2,263.     5
```

The Random Number Generator and Sort Routine
(FORTRAN version)

```
// FOR
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
      FUNCTION RNDX(K,L)
      CALL RANDS(YFL)
      A=K
      B=L
      RNDX=IFIX(A+(B-A+.9999999)*YFL)
      RETURN
      END
// FOR
*LIST SOURCE PROGRAM
*ONE WORD INTEGERS
      SUBROUTINE RANDS(YFL)
      COMMON IX,IY
      IY=IX*899
      IF(IY)5,6,6
    5 IY=IY+32767+1
    6 YFL=IY
      YFL=YFL/32767.
      IX=IY
      RETURN
      END
```

```
// FOR
*ONE WORD INTEGERS
      SUBROUTINE ISORT(N,K,L)
C...  L=1 WILL SORT FROM LOW TO HIGH
C...  L=2 WILL SORT FROM HIGH TO LOW
      DIMENSION K(1)
      LAST=N-1
5     LIM=0
      DO 1 I=1,LAST
      J=I+1
      GO TO (7,8),L
7     IF(K(I)-K(J))1,1,2
8     IF(K(J)-K(I))1,1,2
2     IT=K(I)
      K(I)=K(J)
      K(J)=IT
      LIM=I-1
1     CONTINUE
      IF(LIM)4,4,3
3     LAST=LIM
      GO TO 5
4     RETURN
      END
```

Sample run of COLLIG program (BASIC version)

```
 ENTER THE DATE, PLEASE.  (18 CHARACTER MAXIMUM)
?JULY 31,1975
 DO YOU WANT QUESTIONS FROM 1-SET 1,2-SET 2,3-BOTH, OR 4-EXIT.
 PLEASE ENTER THE CORRESPONDING NUMBER.?3
HOW MANY EXAMS WOULD YOU LIKE?2
 HOW MANY QUESTIONS PER EXAM?5
  PLEASE ENTER AN EXAM CODE NUMBER - UP TO FOUR DIGITS?1538

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -I- - - - - - - - - - -
                                                                I
  NAME:                                                         I
  SECTION:                                                      I
  EXAM: 1538                                                    I  EXAM: 1538
  COPY:    1                                                    I  COPY:    1
  DATE: JULY 31,1975                                            I  JULY 31,1975
                                                                I
                                                                I
                                                                I
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -I- - - - - - - - - - -
QUESTION # 1                                                    I  QUES. 1
     A COMPOUND CONTAINS 37.5 PERCENT CARBON,                   I
12.5 PERCENT HYDROGEN, AND 50.0 PERCENT OXYGEN.                 I
 27. GRAMS OF THIS SUBSTANCE DISSOLVED IN 253.                  I
GRAMS OF WATER WILL FREEZE AT  3.33 DEG. C.                     I
WHAT IS THE MOLECULAR FORMULA OF THE COMPOUND IF                I
IT IS A NON-ELECTROLYTE?                                        I
                                                                I
                                                                I
                                                                I
                                                                I   CH3OH

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -I- - - - - - - - - - -
QUESTION # 2                                                    I  QUES. 2
     CALCULATE (A)- THE FREEZING POINT AND                      I
(B)- THE BOILING POINT OF A SOLUTION CONTAINING                 I
  15. GRAMS OF FERRIC SULFATE, FE2(SO4)3,                       I
DISSOLVED IN   343. GRAMS OF WATER.                             I
                                                                I
                                                                I
                                                                I  F.P.=    -1.
                                                                I  B.P.=   100.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -I- - - - - - - - - - -
QUESTION # 3                                                    I  QUES. 3
     A SOLUTION CONTAINS  3. MOLES OF                           I
ALCOHOL, C2H5OH,                 DISSOLVED IN                   I
BENZENE, (C6H6), AND FREEZES AT  -154.28                        I
DEGREES.  HOW MANY GRAMS OF BENZENE DOES                        I
THIS SOLUTION CONTAIN?  THE FREEZING POINT                      I
OF BENZENE IS 5.5 DEG. AND THE FREEZING POINT                   I
CONSTANT IS 4.90 DEG./M.                                        I
                                                                I
                                                                I
                                                                I
                                                                I   92.00 GRAMS
```

QUESTION # 4

AN UNKNOWN POLYSACCHARIDE IS KNOWN TO HYDROLYZE IN ACID SOLUTION TO SIMPLE SUGARS (GLUCOSE UNITS) OF FORMULA C6H1206. WHEN .0044 MOLES OF THE POLYSACCHARIDE WAS DISSOLVED IN 256. GRAMS OF WATER AT 25 DEG. C., IT WAS FOUND TO PRODUCE AN OSMOTIC PRESSURE OF 233.26 CM. OF HG. CALCULATE THE NUMBER OF GLUCOSE UNITS CONTAINED IN THE POLYSACCHARIDE.

QUES. 4

8. GLUCOSE UNITS

QUESTION # 5

THE OSMOTIC PRESSURE OF A SOLUTION OF 7. GRAMS OF HEMOGLOBIN DISSOLVED IN 157. GRAMS OF WATER IS 87. TORR AT 25 DEG. C. ESTIMATE THE MOLECULAR WEIGHT OF HEMOGLOBIN

QUES. 5

MOLECULAR WEIGHT = 8700.00

NAME:
SECTION:
EXAM: 1538
COPY: 2
DATE: JULY 31,1975

EXAM: 1538
COPY: 2
JULY 31,1975

QUESTION # 1

AN UNKNOWN POLYSACCHARIDE IS KNOWN TO HYDROLYZE IN ACID SOLUTION TO SIMPLE SUGARS (GLUCOSE UNITS) OF FORMULA C6H1206. WHEN .0013 MOLES OF THE POLYSACCHARIDE WAS DISSOLVED IN 215. GRAMS OF WATER AT 25 DEG. C., IT WAS FOUND TO PRODUCE AN OSMOTIC PRESSURE OF 113.36 CM. OF HG. CALCULATE THE NUMBER OF GLUCOSE UNITS CONTAINED IN THE POLYSACCHARIDE.

QUES. 1

11. GLUCOSE UNITS

QUESTION # 2 CALCULATE THE VAPOR PRESSURE OF WATER ABOVE A SOLUTION CONTAINING 137. GRAMS OF METHANOL, CH3OH, IN 518. GRAMS OF WATER AT 47. DEGREES. THE VAPOR PRESSURE OF PURE WATER AT THIS TEMPERATURE IS 77.98 TORR.	QUES. 2 VAPOR PRESSURE= 67.88
QUESTION # 3 A .36 MOLAR SOLUTION OF A WEAK MONOPROTIC ACID BOILED AT 100.19 DEG. C. CALCULATE (A)- THE PERCENT IONIZATION OF THE ACID AND (B)- THE IONIZATION CONSTANT FOR THE ACID.	QUES. 3 PERCENT = 2.78 KEQ. =3.63647E-5
QUESTION # 4 THE OSMOTIC PRESSURE OF A SOLUTION OF 9. GRAMS OF HEMOGLOBIN DISSOLVED IN 127. GRAMS OF WATER IS157. TORR AT 25 DEG. C. ESTIMATE THE MOLECULAR WEIGHT OF HEMOGLOBIN	QUES. 4 MOLECULAR WEIGHT = 7700.00
QUESTION # 5 CALCULATE THE OSMOTIC PRESSURE OF A SOLUTION CONTAINING 20. GRAMS OF SUGAR, C12H22O11, IN 340. GRAMS OF WATER.	QUES. 5 OSMOTIC PRESS.= 3.85 ATM.

DO YOU WANT QUESTIONS FROM 1-SET 1,2-SET 2,3-BOTH, OR 4-EXIT.
PLEASE ENTER THE CORRESPONDING NUMBER.?4

COLLIG Program (in BASIC)

```
 10 DEF FNR(L1,L2)
 20   LET C1=RND(C1)*1000
 30   LET R=L1+(C1-INT(C1/(L2-L1+1))*(L2-L1+1))
 40   RETURN R
 50 FNEND
 60 DEF FNV(T)=7.239E8*EXP(-5136.39/(T+273.15))
 70 DEF FNC(A,B,C)=1000*A/(B*C)
 80 DIM D$[18],A$[10,30],A[4,10],B$[11,30],B[2,11]
 90 FOR I=1 TO 10
100   READ A$[I],A[1,I],A[2,I],A[3,I],A[4,I]
110 NEXT I
120 DATA "ETHYLENE GLYCOL, C2H6O2,",62,38.7,9.7,51.6
130 DATA "ALCOHOL, C2H5OH,",46,52.2,13,34.8
140 DATA "SUGAR, C12H22O11,",342,42.1,6.4,51.5
150 DATA "METHANOL, CH3OH,",32,37.5,12.5,50
160 DATA "GLYCERINE, C3H8O3,",92,39.1,8.7,52.2
170 DATA "PROPYLENE GLYCOL, C3H8O2,",76,47.4,10.5,42.1
180 DATA "ACETALDEHYDE,C2H4O,",44,54.5,9.1,36.4
190 DATA "GLUCOSE,C6H12O6,",180,40,6.7,53.3
200 DATA "ISOPROPYL ALCOHOL, C3H8O,",60,60,13.3,26.7
210 DATA "ACETONE, C3H6O,",58,62.1,10.3,27.6
220 FOR I=1 TO 11
230   READ B$[I],B[1,I],B[2,I]
240 NEXT I
250 DATA "AMMONIUM PHOSPHATE, (NH4)3PO4,",149,4
260 DATA "ALUMINUM ACETATE, AL(C2H3O2)3,",204,4
270 DATA "FERRIC SULFATE, FE2(SO4)3,",400,5
280 DATA "POTASSIUM OXALATE, K2C2O4,",166.2,3
290 DATA "FERROUS BROMIDE, FEBR2,",215.7,3
300 DATA "NICKEL CHLORIDE, NICL2,",127.6,3
310 DATA "ALUMINUM CHLORIDE, ALCL3,",133.3,4
320 DATA "ZINC SULFATE, ZNSO4,",161.5,2
330 DATA "CALCIUM CHLORIDE, CACL2,",111,3
340 DATA "SODIUM PHOSPHATE, NA3PO4,",164,4
350 DATA "MAGNESIUM PHOSPHATE,MG3(PO4)2,",263,5
360 PRINT " ENTER THE DATE, PLEASE.  (18 CHARACTER MAXIMUM)"
370 INPUT D$
380 PRINT @
    " DO YOU WANT QUESTIONS FROM 1-SET 1,2-SET 2,3-BOTH, OR 4-EXIT."
390 PRINT " PLEASE ENTER THE CORRESPONDING NUMBER.";
400 INPUT F1
410 LET L1=1
420 LET U=20
430 GOTO F1 OF 460,480,490,2290
440 PRINT " PLEASE ENTER 1, 2, 3, OR 4";
450 GOTO 400
460 LET U=10
470 GOTO 490
480 LET L1=11
490 PRINT " HOW MANY EXAMS WOULD YOU LIKE";
500 INPUT E
510 PRINT " HOW MANY QUESTIONS PER EXAM";
520 INPUT Q
```

```
 530 PRINT "  PLEASE ENTER AN EXAM CODE NUMBER - UP TO FOUR DIGITS";
 540 INPUT C
 550 LET C1=C
 560 FOR E1=1 TO E
 570   MAT J=CON
 580   MAT J=(999)*J
 590   FOR Q1=1 TO Q
 600     R=INT(FNR(L1,U))
 610     FOR Q2=1 TO Q1
 620       IF (J[Q2])-R=0 THEN 600
 630     NEXT Q2
 640     LET J[Q1]=R
 650   NEXT Q1
 660   REM ---> CALL TO ISORT.
 670   PRINT CHR$(12)
 680   PRINT USING 690;C,C,E1,E1,D$,D$
 690   IMAGE "- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -I","- &
- - - - - - - - - -"/51X,I/2X,"NAME:",44X,I/2X,"SECTION:",41X,I/2X,"EXAM:",X&
4D,39X,I2X,"EXAM:",X4D/2X,"COPY:",X3D40X,I2X,"COPY:",X3D/2X,"DATE:",X18A,&
25X,I2X,18A
 700   PRINT TAB(51);"I";LIN(1),TAB(51),"I",LIN(1),TAB(51),"I"
 710   FOR Q3=1 TO Q
 720     LET Q4=J[Q3]
 730     PRINT "- - - - - - - - - - - - - - - - - - - - - - - - - - - - -I";&
     "- - - - - - - - - - "
 740     PRINT "QUESTION #";Q3;TAB(51);"I  QUES.";Q3
 750     GOSUB 810
 760   NEXT Q3
 770   PRINT LIN(3)
 780 NEXT E1
 790 GOTO 380
 800 STOP
 810 GOTO Q4 OF 840,890,940,990,1040,1110,1160,1230,1300,1360
 820 GOTO (Q4-10) OF 1410,1480,1530,1640,1710,1870,2020,2090,2140,2210
 830 RETURN
 840 G=INT(FNR(2,20)),L=INT(FNR(1,10)),W=INT(FNR(100,250))
 850 R=FNC(G,W,A[1,L]),T1=-1.86*R,T2=100+.52*R
 860 PRINT USING 870;G,A$[L],W,T1,T2
 870 IMAGE "     CALCULATE (A)- THE FREEZING POINT AND",9X,I/"(B)- THE &
BOILING POINT OF A SOLUTION OF",12X,I/DDD.," GRAMS OF ",30A,7X,I/"PER",&
DDDDDD.," GRAMS OF WATER.",25X,I/51X,I/51X,I/51X,I,"  F.P.=",DDDDDD./51&
X,I,"  B.P.=",DDDDDD./
 880 RETURN
 890 G=INT(FNR(10,15)),L=INT(FNR(1,11)),W=INT(FNR(300,350))
 900 R=FNC(G,W,B[1,L])*B[2,L],T1=-1.86*R,T2=100+.52*R
 910 PRINT USING 920;G,B$[L],W,T1,T2
 920 IMAGE "     CALCULATE (A)- THE FREEZING POINT AND",9X,I/"(B)- THE &
BOILING POINT OF A SOLUTION CONTAINING",4X,I/DDDD.," GRAMS OF ",30A,6X,&
I/"DISSOLVED IN ",DDDDD.," GRAMS OF WATER.",16X,I/51X,I/51X,I/51X,I,"  &
F.P.=",DDDDDD./51X,I,"  B.P.=",DDDDDD./
 930 RETURN
 940 G=INT(FNR(10,30)),L=INT(FNR(1,10)),W=INT(FNR(250,600))
 950 R=FNC(G,W,A[1,L])*22.4
 960 PRINT USING 970;G,A$[L],W,R
 970 IMAGE "     CALCULATE THE OSMOTIC PRESSURE OF A",11X,I/"SOLUTION C&
ONTAINING",DDDD.," GRAMS OF",18X,I/30A,21X,I/"IN ",DDDDDD.," GRAMS OF W&
ATER.",25X,I/51X,I/51X,I/51X,I,"  OSMOTIC PRESS.="/51X,I,2X,DDDDDD.DD,"&
 ATM."/
```

```
 980 RETURN
 990 A=INT(FNR(60,150)),G=INT(FNR(5,15)),W=INT(FNR(100,300))
1000 T=FNC(G,W,A)*-1.86
1010 PRINT USING 1020;T,G,W,A
1020 IMAGE "     AN AQUEOUS SOLUTION FREEZES AT",3D.DD,10X,I/"DEGREES A&
ND CONTAINS",4D.," GRAMS OF A",15X,I/"NON-ELECTROLYTE IN",5D.," GRAMS O&
F WATER."11X,I/"CALCULATE THE MOLECULAR WEIGHT OF THE SOLUTE.",6X,I/51X&
,I/51X,I/51X,I,"  MOLECULAR WEIGHT:"/51X,I,XX5D.DD/
1030 RETURN
1040 A=INT(FNR(60,20)),G=INT(FNR(10,30)),W=INT(FNR(150,250))
1050 T1=4.9*FNC(G,W,A)
1060 PRINT USING 1070;T1,G
1070 IMAGE "     AN ORGANIC SOLUTE DISSOLVED IN BENZENE,",7X,I/"(C6H6),&
 DEPRESSED THE FREEZING POINT OF BENZENE",4X,I/3D.DD," DEGREES.  ANALYS&
IS OF THE SOLUTION SHOWED",3X,I/"THAT IT CONTAINED",4D," GRAMS OF SOLUT&
E IN",11X,I
1080 PRINT USING 1090;W,A
1090 IMAGE 4D.," GRAMS OF BENZENE.  THE FREEZING POINT OF",5X,I/"BENZEN&
E IS 5.5 DEG. C. AND THE DEPRESSION",10X,I/"CONSTANT IS 4.90 DEG./M.   &
CALCULATE THE",11X,I/"MOLECULAR WEIGHT OF THE SOLUTE.",20X,I/51X,I/51X,&
I/51X,I,"  MOLECULAR WT.="/51X,I,2X4D.DD/
1100 RETURN
1110 G=INT(FNR(5,10)),L=INT(FNR(1,11)),A=INT(FNR(50,150))
1120 T1=100+.52*FNC(G,A,B[1,L])*B[2,L]
1130 PRINT USING 1140;G,B$[L],T1,A
1140 IMAGE "     AN AQUEOUS SOLUTION CONTAINS",4D.," GRAMS",7X,I/"OF ",&
10A," AND BOILS AT",5X,I/4D.DD," DEGREES.  HOW MANY GRAMS OF WATER ARE &
IN",3X,I/"THIS SOLUTION?",37X,I/51X,I/51X,I/51X,I/51X,I,XX5D.DD," GRAMS&
"/
1150 RETURN
1160 G=INT(FNR(1,3)),L=INT(FNR(1,10)),A=INT(FNR(1,4))*A[1,L]
1170 T1=5.5-4900*G/A
1180 PRINT USING 1200;G,A$[L],T1
1190 PRINT USING 1210;A
1200 IMAGE "     A SOLUTION CONTAINS ",DD.," MOLES OF",14X,I/30A," DISSO&
LVED IN",8X,I/"BENZENE, (C6H6), AND FREEZES AT ",5D.DD,11X,I/"DEGREES.  H&
OW MANY GRAMS OF BENZENE DOES",11X,I
1210 IMAGE "THIS SOLUTION CONTAIN?  THE FREEZING POINT",9X,I/"OF BENZENE&
 IS 5.5 DEG. AND THE FREEZING POINT",6X,I/"CONSTANT IS 4.90 DEG./M.",27X&
,I/51X,I/51X,I/51X,I/51X,I,3X,DDDD.DD," GRAMS"/
1220 RETURN
1230 T1=INT(FNR(40,80)),V=FNV(T1),G=INT(FNR(100,150)),L=INT(FNR(1,10))
1240 W=INT(FNR(500,800)),P=(W/18)/(W/18+G/A[1,L])*V
1250 PRINT USING 1270;G,A$[L],W,T1,V
1260 PRINT USING 1280;P
1270 IMAGE 5X,"CALCULATE THE VAPOR PRESSURE OF WATER ABOVE",3X,I/"A SOLU&
TION CONTAINING",4D.X,"GRAMS OF",16X,I/30AX,"IN",5D.X,"GRAMS OF",3X,I/"WA&
TER AT",4D.X,"DEGREES.  THE VAPOR PRESSURE",9X,I/"OF PURE WATER AT THIS &
TEMPERATURE IS",4D.DDX,"TORR.",2X,I
1280 IMAGE 2(51X,I ),51X,IXX,"VAPOR PRESSURE="/,51X,IXXDDDD.DD
1290 RETURN
1300 G=INT(FNR(5,10)),W=INT(FNR(20,50)),T1=80+2.53*FNC(G,W,394)
1310 PRINT USING 1330;G,W
1320 PRINT USING 1340;T1
1330 IMAGE 5X,"CALCULATE THE BOILING POINT OF A SOLUTION",5X,I/"OF",4D.X&
,"GRAMS OF IODOFORM, (CHI3), IN",4D.X,"GRAMS",3X,I/"OF BENZENE (C6H6).  &
THE BOILING POINT OF BENZENE",3X,I/"IS 80. DEG. C. AND THE BOILING POINT&
 CONSTANT",6X,I
```

```
1340 IMAGE "IS 2.53 DEG./M. (A.WT. C=12, H=1, I=127).",10XI/2(51XI/),51&
XIXX,"B.P.=",DDDD.DD/51XIXXXXXXXX,"DEG.C."
1350 RETURN
1360 A=INT(FNR(60,150)),G=INT(FNR(10,20)),W=INT(FNR(100,200))
1370 C5=22.4*76*FNC(G,W,A)
1380 PRINT USING 1390;C5,G,W,A
1390 IMAGE 5X,"CALCULATE THE MOLECULAR WEIGHT OF A",11XI/"NON-ELECTROLY&
TE WHICH PRODUCES AN OSMOTIC PRESSURE",XI/"OF",5D.X,"CM OF HG WHEN",4D.&
X,"GRAMS ARE DISSOLVED",4XI/"IN",5D.X,"GRAMS OF WATER.",27XI/51XI/51XI/&
51XI2X,"MOLECULAR WT.:"/51XI4X4D.DD
1400 RETURN
1410 L=INT(FNR(1,11)),T1=INT(FNR(40,80)),V=FNV(T1),W=INT(FNR(100,200))
1420 A=INT(FNR(20,75)),F5=W/18,F6=A*B[2,L]/B[1,L],F7=F5*V/(F5+F6)
1430 PRINT USING 1450;B$[L],W,T1
1440 PRINT USING 1460;F7,V,A
1450 IMAGE 5X,"HOW MANY GRAMS OF",29XI/30AX,"MUST BE ADDED TO",4XI/3D.X&
,"GRAMS OF WATER AT",3D.X,"DEG. C. TO LOWER",8XI
1460 IMAGE "THE VAPOR PRESSURE OF WATER TO",3D.2DX,"TORR?  THE",4XI/"VA&
POR PRESSURE OF WATER AT THIS TEMPERATURE IS",5XI/3D.2DX,"TORR.",39XI/3&
(51XI/),51XI2X,4D.2DX,"GRAMS"/
1470 RETURN
1480 G=INT(FNR(5,10)),W=INT(FNR(100,200)),A=6700+1000*INT(FNR(1,10))
1490 T=22.4*760*FNC(G,W,A)
1500 PRINT USING 1510;G,W,T,A
1510 IMAGE 5X,"THE OSMOTIC PRESSURE OF A SOLUTION OF",4D.4XI/"GRAMS OF &
HEMOGLOBIN DISSOLVED IN",4D.X,"GRAMS OF",5XI/"WATER IS",3D.X,"TORR AT 2&
5 DEG. C.  ESTIMATE THE",5XI/"MOLECULAR WEIGHT OF HEMOGLOBIN",21XI/2(5&
1XI/),51XI2X,"MOLECULAR WEIGHT ="/51XI11X,5D.2D/
1520 RETURN
1530 L=INT(FNR(1,11)),T1=INT(FNR(40,80)),G1=INT(FNR(40,70))
1540 W1=INT(FNR(300,500)),G2=INT(FNR(71,100)),W2=INT(FNR(300,500))
1550 V=FNV(T1),Y=G1*(W1+W2)/(G1+G2),S2=G2+Y,S1=G1+W1+W2-Y
1560 F5=Y/18,F6=G2*B[2,L]/B[1,L],P=F5*V/(F5+F6)
1570 PRINT USING 1600;B$[L],T1
1580 PRINT USING 1610;G1,W1,G2,W2
1590 PRINT USING 1620;V,S1,S2,P
1600 IMAGE 5X,"TWO BEAKERS LABELED A AND B, BOTH CONTAINING",2XI/"SOLUT&
IONS OF ",30A,8XI/"IN WATER ARE PLACED IN AN EVACUATED BELL-JAR AT",4XI&
/4D.X,"DEG. C. AND ALLOWED TO EQUILIBRATE.",10XI
1610 IMAGE "INITIALLY, A CONTAINS",4D.X,"GRAMS OF SOLUTE IN",6XI/3D.X,"&
GRAMS OF WATER AND B CONTAINS",4D.X,"GRAMS OF",3XI/"SOLUTE IN",4D.X,"GR&
AMS OF WATER.  CALCULATE:",9XI/"(A)- THE WEIGHT OF EACH SOLUTION AT EQU&
ILIBRIUM",4XI
1620 IMAGE "(B)- THE VAPOR PRESSURE OF WATER IN THE BELL-JAR.",2XI/"THE&
 VAPOR PRESSURE OF WATER AT THIS TEMPERATURE",4XI/"IS",4D.DX,"TORR.",37&
XI/51XI2X,"SOL. A ="/51XI6X,3D.DDX,"GRAMS"/51XI2X,"SOL. B ="/51XI6X3D.D&
DX,"GRAMS"/51XI2X,"V.P. =",4D.DDX,"TORR"/
1630 RETURN
1640 A=INT(FNR(5,15)),G=FNR(1,5)/999.99,W=INT(FNR(100,300))
1650 P=76*22.4*G*A*1000/W
1660 PRINT USING 1680;G,W
1670 PRINT USING 1690;P,A
1680 IMAGE 5X,"AN UNKNOWN POLYSACCHARIDE IS KNOWN TO",9XI/"HYDROLYZE IN&
 ACID SOLUTION TO SIMPLE SUGARS",8XI/"(GLUCOSE UNITS) OF FORMULA C6H120&
6.  WHEN",2D.4D3XI/"MOLES OF THE POLYSACCHARIDE WAS DISSOLVED IN",4D.2X&
I/"GRAMS OF WATER AT 25 DEG. C., IT WAS FOUND TO",6XI
1690 IMAGE "PRODUCE AN OSMOTIC PRESSURE OF",5D.DDX,"CM. OF HG.",2XI/"CA&
LCULATE THE NUMBER OF GLUCOSE UNITS CONTAINED",4XI/"IN THE POLYSACCHARI&
DE.",29XI/3(51XI/),51XIXX,4D.X,"GLUCOSE UNITS"/
```

```
1700 RETURN
1710 L=INT(FNR(1,5)),G=INT(FNR(5,10)),W=INT(FNR(10,20))
1720 W1=INT(FNR(200,400))
1730 IF INT(FNR(1,2))=2 THEN 1790
1740 L2=INT(FNR(6,10)),R=FNC(G,W1,A[1,L])+FNC(W,W1,A[1,L2])
1750 F9=-1.86*R,B9=.52*R
1760 PRINT USING 1840:G,A$[L],W,A$[L2],W1
1770 PRINT USING 1850:F9,B9
1780 RETURN
1790 L2=INT(FNR(6,11))
1800 R=FNC(G,W1,B[1,L])*B[2,L]+FNC(W,W1,B[1,L2])*B[2,L2]
1810 F9=-1.86*R,B9=.52*R
1820 PRINT USING 1840:G,B$[L],W,B$[L2],W1
1830 PRINT USING 1850:F9,B9
1840 IMAGE 5X,"A SOLUTION CONTAINS",4D.X,"GRAMS OF",13XI/30A,X,"AND",4D&
.X,"GRAMS OF",3XI/30A,X,"IN",5D.X,"GRAMS OF",3XI/"WATER.  CALCULATE (A)&
- THE FREEZING POINT AND",6XI/"(B)- THE BOILING POINT OF THIS SOLUTION.&
 ASSUME",3XI
1850 IMAGE "THE EFFECT OF EACH SOLUTION IS ADDITIVE.",11XI/2(51XI/),51X&
12X,"F.P. =",5D.2D/51XI2X,"B.P. =",5D.3D/
1860 RETURN
1870 L=INT(FNR(1,10)),G=INT(FNR(5,30)),W=INT(FNR(200,300))
1880 T1=FNC(G,W,A[1,L])
1890 FOR A=1 TO 30
1900   IF A$[L,A;1]="," THEN 1920
1910 NEXT A
1920 LET Z1=A+1
1930 FOR A=Z1 TO 30
1940   IF A$[L,A;1]="," THEN 1960
1950 NEXT A
1960 Z2=A-1
1970 PRINT USING 1990:A[2,L],A[3,L],A[4,L],G,W,T1
1980 PRINT USING 2000:A$[L,Z1,Z2]
1990 IMAGE 5X,"A COMPOUND CONTAINS",3D.DX,"PERCENT CARBON,",6XI/2D.DX,"&
PERCENT HYDROGEN, AND",3D.DX,"PERCENT OXYGEN.",4XI/3D.X,"GRAMS OF THIS &
SUBSTANCE DISSOLVED IN",4D.,5XI/"GRAMS OF WATER WILL FREEZE AT",3D.2DX,&
 DEG. C.",8XI
2000 IMAGE "WHAT IS THE MOLECULAR FORMULA OF THE COMPOUND IF",3XI/"IT I&
S A NON-ELECTROLYTE?",27XI/3(51XI/),51XIXX,19A/
2010 RETURN
2020 C9=INT(FNR(1,100))/99.999,A=INT(FNR(1,4))/99.999,P=100*A/C9
2030 C0=C9*A**2/(1-A),B9=100+.52*C9*(1+A)
2040 PRINT USING 2060:C9,B9
2050 PRINT USING 2070:P,C0
2060 IMAGE 5X,"A",2D.2DX,"MOLAR SOLUTION OF A WEAK MONOPROTIC",4XI/"ACI&
D BOILED AT",4D.2DX,"DEG. C.   CALCULATE (A)-",5XI/"THE PERCENT IONIZAT&
ION OF THE ACID AND (B)- THE",4XI/"IONIZATION CONSTANT FOR THE ACID.",1&
3XI
2070 IMAGE 2(51XI/),51XIXX,"PERCENT =",4D.DD/51XIXX,"KEQ. =",K
2080 RETURN
2090 G=INT(FNR(2,15))/9.999,W=INT(FNR(500,800)),A=SQR(.000018*C)
2100 B9=100+.52*G*1000/W*(1+A)
2110 PRINT USING 2120:G,W,B9
2120 IMAGE 5X,"THE IONIZATION CONSTANT, K, FOR ACETIC ACID,",2XI/"HC2H3&
O2, IS 1.8 E-5.  CALCULATE THE BOILING POINT",2XI/"OF A SOLUTION COMPOS&
ED OF",2D.DX,"MOLES OF ACID IN",5XI/3D.X"ML. OF SOLUTION.",30XI/2(51XI/&
),51XIXX,"B.P.=",3D.DD/51XI9X,"DEG.C."/
2130 RETURN
```

```
2140 C9=INT(FNR(10,20))/99.999,C0=INT(FNR(1,5))/99.999
2150 A=22.4*76*13.6*(C9-C0)/(12*2.54)
2160 PRINT USING 2180;C9
2170 PRINT USING 2190;C0,A
2180 IMAGE 5X,"IF OSMOSIS IS RESPONSIBLE FOR SAP RISING IN",3XI/"A TREE&
, ESTIMATE THE HEIGHT IN FEET TO WHICH SAP",3XI/"CAN RISE AT 25 DEG. C.&
 IF THE SAP IS",2D.2DX,"MOLAR",4XI/"IN SUGAR, C6H1206, AND THE WATER OU&
TSIDE THE SAP-",2XI
2190 IMAGE "BEARING TUBULE CONTAINS A NON-ELECTROLYTE AT A",5XI/"CONCEN&
TRATION OF",2D.2DX,"MOLAR.  NOTE THAT 1.0 CM",5XI/"OF HG EXERTS THE SAM&
E PRESSURE AS 13.6 CM OF WATER.",I/3(51XI/),51XIXX,5D.2DX,"FEET"
2200 RETURN
2210 P=INT(FNR(20,50)),P1=100-P,W2=INT(FNR(2,5)),W1=INT(FNR(10,50))
2220 W3=P*W2/100,W4=P1*W2/100,T1=(FNC(W3,W1,423)+FNC(W4,W1,180))*-1.86
2230 PRINT USING 2250;W2,W1,T1
2240 PRINT USING 2260;P
2250 IMAGE 5X,"'STREET' HEROIN (MW=423) IS SOLD IMPURE",7XI/"MIXED WITH&
 GLUCOSE, C6H1206 (MW=180).  WHEN",3D.4XI/"GRAMS OF IMPURE SAMPLE WAS M&
IXED WITH",3D.X,"GRAMS",4XI/"OF WATER, THE SOLUTION FROZE AT",4D.2DX,"D&
EG. C.",5XI
2260 IMAGE "ESTIMATE THE WEIGHT PERCENT OF HEROIN IN THE",7XI/"SAMPLE."&
,44XI/3(51XI/),51XI2X,"PERCENT HEROIN ="/51XI15X,3D.DD/
2270 RETURN
2280 STOP
2290 END
>
```

Unit Test on Colligative Properties of Solutions

TEST 1

1. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 5.370 G OF CH_3CONH_2 IN 92 G OF WATER AT 38 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 38 DEG C IS 55.6 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

2. A SOLUTION OF 3.530 G OF A NON-ELECTROLYTE IN 138 G OF WATER BOILS AT 100.2183 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

3. HOW MANY GRAMS OF $C_{14}H_{23}NO_9$ MUST BE ADDED TO 109.50 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.008 MM HG LESS THAN THAT OF PURE WATER AT 23 DEG C. THE VAPOR PRESSURE OF WATER AT 23 DEG C IS 25.1 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

4. THE TWO LIQUIDS BENZENE AND O-XYLENE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 83.92 DEG C ARE 804.27 AND 312.16 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 83.92 DEG C, IN WHICH THE MOLE FRACTION OF BENZENE IS 0.987?

5. A SOLUTION OF 8.910 G OF A CERTAIN NON-ELECTROLYTE IN 267 G OF WATER FREEZES AT -1.0889 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

6. HOW MANY GRAMS OF THE $BrCH_2CONH_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -1.146 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

7. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 0.010 G OF $BrFCHCONH_2$ IN 271 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

TEST 1

1. 5.466E+01 TORR
2. 6.00E+01
3. 6.82E-01
4. 7.98E+02 MM HG
5. 5.70E+01
6. 8.50E+00
7. 100.1212

Unit Test on Colligative Properties of Solutions

TEST 2

1. A SOLUTION OF 9.023 G OF A CERTAIN NON-ELECTROLYTE IN 342 G OF WATER FREEZES AT -0.2020 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

2. THE TWO LIQUIDS BENZENE AND TOLUENE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 87.32 DEG C ARE 844.98 AND 540.10 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 87.32 DEG C, IN WHICH THE MOLE FRACTION OF BENZENE IS 0.172?

3. A SOLUTION OF 9.780 G OF A NON-ELECTROLYTE IN 76 G OF WATER BOILS AT 101.0972 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

4. HOW MANY GRAMS OF THE $C_6H_4Cl_2O_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -1.013 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

5. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 5.320 G OF $C_{12}H_{22}O_{11}$ IN 71 G OF WATER AT 3 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 3 DEG C IS 7.6 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

6. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 0.710 G OF $ClCH_2CONH_2$ IN 336 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

7. HOW MANY GRAMS OF $C_6H_4Cl_2O_2$ MUST BE ADDED TO 418.00 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.022 MM HG LESS THAN THAT OF PURE WATER AT 37 DEG C. THE VAPOR PRESSURE OF WATER AT 37 DEG C IS 52.9 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

TEST 2

1. 2.59E+02
2. 5.93E+02 MM HG
3. 6.00E+01
4. 9.75E+00
5. 7.539E+00 TORR
6. 100.0116
7. 1.71E+00

Unit Test on Colligative Properties of Solutions

TEST 3

1. HOW MANY GRAMS OF $BrFCHCONH_2$ MUST BE ADDED TO 92.99 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.169 MM HG LESS THAN THAT OF PURE WATER AT 84 DEG C. THE VAPOR PRESSURE OF WATER AT 84 DEG C IS 422.2 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

2. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 4.650 G OF $Cl_2CHCH(OH)_2$ IN 25 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

3. A SOLUTION OF 0.780 G OF A CERTAIN NON-ELECTROLYTE IN 127 G OF WATER FREEZES AT -0.2507 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

4. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 5.610 G OF $C_{11}H_{20}O_{10}$ IN 102 G OF WATER AT 69 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 69 DEG C IS 231.5 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

5. HOW MANY GRAMS OF THE $C_{12}H_{22}O_{11}$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.246 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

6. A SOLUTION OF 0.250 G OF A NON-ELECTROLYTE IN 301 G OF WATER BOILS AT 100.0082 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

7. THE TWO LIQUIDS PENTANE AND HEPTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 90.15 DEG C ARE 1669.35 AND 673.61 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 90.15 DEG C, IN WHICH THE MOLE FRACTION OF PENTANE IS 0.199?

TEST 3

1. 3.22E-01
2. 100.7272
3. 3.96E+02
4. 2.308E+02 TORR
5. 4.53E+00
6. 1.56E+02
7. 8.72E+02 MM HG

Unit Test on Colligative Properties of Solutions

TEST 4

1. A SOLUTION OF 4.020 G OF A NON-ELECTROLYTE IN 380 G OF WATER BOILS AT 100.0450 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. HOW MANY GRAMS OF THE $Cl_2CHCH(OH)_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -1.125 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

3. THE VAPOR PRESSURE OF HEXANE AND CYCLOHEXANE AT 72.29 DEG C ARE 811.56 AND 676.63 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF HEXANE IN A CYCLOHEXANE SOLUTION WHICH BOILS AT 72.29 DEG C AT 760 MM HG?

4. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 8.770 G OF $C_5H_{10}O_5$ IN 361 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

5. A SOLUTION OF 9.030 G OF A CERTAIN NON-ELECTROLYTE IN 469 G OF WATER FREEZES AT -0.2252 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

6. HOW MANY GRAMS OF $C_6H_{12}O_6$ MUST BE ADDED TO 348.50 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.015 MM HG LESS THAN THAT OF PURE WATER AT 59 DEG C. THE VAPOR PRESSURE OF WATER AT 59 DEG C IS 150.5 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

7. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 6.420 G OF $C_7H_5ClO_2$ IN 95 G OF WATER AT 17 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 17 DEG C IS 17.8 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

TEST 4

1. 1.38E+02
2. 7.92E+00
3. 6.18E-01
4. 100.0828
5. 1.59E+02
6. 3.42E-01
7. 1.767E+01 TORR

Unit Test on Colligative Properties of Solutions

TEST 5

1. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 0.680 G OF $C_8H_{10}O_2$ IN 84 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

2. HOW MANY GRAMS OF THE $BrCH_2CONH_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.811 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

3. A SOLUTION OF 0.710 G OF A NON-ELECTROLYTE IN 188 G OF WATER BOILS AT 100.3046 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

4. THE TWO LIQUIDS HEXANE AND HEPTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 93.23 DEG C ARE 1093.63 AND 705.05 MM HG RESPECTIVELY WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 93.23 DEG C, IN WHICH THE MOLE FRACTION OF HEXANE IS 0.084?

5. A SOLUTION OF 9.610 G OF A CERTAIN NON-ELECTROLYTE IN 598 G OF WATER FREEZES AT -0.0547 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

6. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 0.670 G OF $Cl_2CHCH(OH)_2$ IN 23 G OF WATER AT 62 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 62 DEG C IS 171.7 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

7. HOW MANY GRAMS OF $C_6H_4Cl_2O_2$ MUST BE ADDED TO 90.50 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.112 MM HG LESS THAN THAT OF PURE WATER AT 57 DEG C. THE VAPOR PRESSURE OF WATER AT 57 DEG C IS 137.6 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

TEST 5

1. 100.0300
2. 6.02E+00
3. 6.00E+01
4. 7.38E+02 MM HG
5. 5.46E+02
6. 1.710E+02 TORR
7. 7.32E-01

Unit Test on Colligative Properties of Solutions

TEST 6

1. A SOLUTION OF 2.720 G OF A NON-ELECTROLYTE IN 218 G OF WATER BOILS AT 100.0351 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

2. HOW MANY GRAMS OF THE $HOCH_2CHO$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -2.320 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

3. A SOLUTION OF 7.330 G OF A CERTAIN NON-ELECTROLYTE IN 248 G OF WATER FREEZES AT -0.2776 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

4. THE TWO LIQUIDS PENTANE AND HEPTANE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 71.87 DEG C ARE 1315.73 AND 505.04 MM HG RESPECTIVELY WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 71.87 DEG C, IN WHICH THE MOLE FRACTION OF PENTANE IS 0.719?

5. HOW MANY GRAMS OF $C_{12}H_{22}O_{11}$ MUST BE ADDED TO 155.00 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.072 MM HG LESS THAN THAT OF PURE WATER AT 34 DEG C. THE VAPOR PRESSURE OF WATER AT 34 DEG C IS 45.3 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

6. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 4.590 G OF $C_6H_4Cl_2O_2$ IN 90 G OF WATER AT 29 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 29 DEG C IS 34.8 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

7. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 9.280 G OF $C_{14}H_{23}NO_9$ IN 342 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

TEST 6

1. 1.82E+02
2. 7.49E+00
3. 1.98E+02
4. 1.09E+03 MM HG
5. 4.67E+00
6. 3.463E+01 TORR
7. 100.0396

Unit Test on Colligative Properties of Solutions

TEST 7

1. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 9.080 G OF $HOCH_2CHO$ IN 352 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

2. A SOLUTION OF 3.840 G OF A NON-ELECTROLYTE IN 80 G OF WATER BOILS AT 100.1373 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

3. HOW MANY GRAMS OF $BrFCHCONH_2$ MUST BE ADDED TO 377.99 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.438 MM HG LESS THAN THAT OF PURE WATER AT 82 DEG C. THE VAPOR PRESSURE OF WATER AT 82 DEG C IS 390.8 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

4. HOW MANY GRAMS OF THE $ClCH_2CONH_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.225 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

5. LIQUIDS HEXANE AND CYCLOHEXANE FORM IDEAL SOLUTIONS. THE VAPOR PRESSURE OF PURE CYCLOHEXANE IS 703.37 TORR AT THE BOILING POINT OF A SOLUTION PREPARED FROM 3.030 MOLES OF CYCLOHEXANE AND 1.970 MOLES OF HEXANE. WHAT IS THE VAPOR PRESSURE OF PURE HEXANE AT THIS TEMPERATURE?

6. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 9.350 G OF $C_{11}H_{20}O_{10}$ IN 103 G OF WATER AT 72 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 72 DEG C IS 262.1 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

7. A SOLUTION OF 4.460 G OF A CERTAIN NON-ELECTROLYTE IN 517 G OF WATER FREEZES AT -0.0634 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

TEST 7

1. 100.2199
2. 1.79E+02
3. 3.67E+00
4. 1.13E+00
5. 8.47E+02 TORR
6. 2.608E+02 TORR
7. 2.53E+02

Unit Test on Colligative Properties of Solutions

TEST 8

1. THE TWO LIQUIDS TOLUENE AND P-XYLENE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 137.50 DEG C ARE 1074.71 AND 755.14 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 137.50 DEG C, IN WHICH THE MOLE FRACTION OF TOLUENE IS 0.326?

2. HOW MANY GRAMS OF $C_{10}H_8N_2$ MUST BE ADDED TO 339.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.384 MM HG LESS THAN THAT OF PURE WATER AT 71 DEG C. THE VAPOR PRESSURE OF WATER AT 71 DEG C IS 251.6 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

3. A SOLUTION OF 3.280 G OF A NON-ELECTROLYTE IN 475 G OF WATER BOILS AT 100.0227 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

4. HOW MANY GRAMS OF THE $C_6H_{12}O_6$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.942 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

5. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 0.760 G OF $CO(NH_2)_2$ IN 494 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

6. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 8.900 G OF $C_6H_4Cl_2O_2$ IN 64 G OF WATER AT 3 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 3 DEG C IS 7.6 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

7. A SOLUTION OF 6.150 G OF A CERTAIN NON-ELECTROLYTE IN 310 G OF WATER FREEZES AT -0.1264 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

TEST 8

1. 8.59E+02 MM HG
2. 4.50E+00
3. 1.56E+02
4. 9.12E+00
5. 100.0131
6. 7.464E+00 TORR
7. 2.92E+02

Unit Test on Colligative Properties of Solutions

TEST 9

1. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 3.920 G OF $C_6H_{14}O_6$ IN 439 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

2. HOW MANY GRAMS OF $C_{12}H_{22}O_{11}$ MUST BE ADDED TO 207.49 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.006 MM HG LESS THAN THAT OF PURE WATER AT 27 DEG C. THE VAPOR PRESSURE OF WATER AT 27 DEG C IS 31.2 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

3. THE TWO LIQUIDS TOLUENE AND P-XYLENE FORM AN IDEAL SOLUTION. THEIR VAPOR PRESSURES AT 121.64 DEG C ARE 881.11 AND 610.63 MM HG RESPECTIVELY. WHAT IS THE TOTAL VAPOR PRESSURE OVER A SOLUTION OF THESE TWO LIQUIDS AT 121.64 DEG C, IN WHICH THE MOLE FRACTION OF TOLUENE IS 0.966?

4. HOW MANY GRAMS OF THE $C_8H_{10}O_2$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.466 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

5. A SOLUTION OF 1.63[illegible] G OF A NON-ELECTROLYTE IN 129 G OF WATER BOILS AT 100.1077 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

6. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 1.500 G OF CH_3CSNH_2 IN 66 G OF WATER AT 23 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 23 DEG C IS 25.1 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

7. A SOLUTION OF 8.030 G OF A CERTAIN NON-ELECTROLYTE IN 338 G OF WATER FREEZES AT -0.0913 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

TEST 9

1. 100.0251
2. 7.42E-01
3. 8.72E+02 MM HG
4. 3.46E+00
5. 6.00E+01
6. 2.493E+01 TORR
7. 4.84E+02

TEST 10

1. CALCULATE THE BOILING POINT AT 1 ATM PRESSURE OF A SOLUTION OF 5.260 G OF $C_{11}H_{20}O_{10}$ IN 369 G OF WATER. (THIS IS A NON-VOLATILE SOLUTE.)

2. A SOLUTION OF 1.320 G OF A NON-ELECTROLYTE IN 214 G OF WATER BOILS AT 100.0414 DEG C AT 760 MM HG. WHAT IS THE MOLECULAR WEIGHT OF THIS NON-ELECTROLYTE?

3. HOW MANY GRAMS OF THE $C_{14}H_{23}NO_9$ WOULD HAVE TO BE DISSOLVED IN 100 G OF WATER TO GIVE A SOLUTION FREEZING AT -0.141 DEG C? (THIS IS A NON-VOLATILE SOLUTE.)

4. CALCULATE THE VAPOR PRESSURE OF WATER OVER A SOLUTION CONTAINING 6.450 G OF $BrFCHCONH_2$ IN 26 G OF WATER AT 87 DEG C. THE VAPOR PRESSURE OF PURE WATER AT 87 DEG C IS 473.3 TORR. (THIS IS A NON-VOLATILE SOLUTE.)

5. THE VAPOR PRESSURE OF BENZENE AND TOLUENE AT 89.62 DEG C ARE 873.12 AND 559.67 MM HG RESPECTIVELY. THE TWO LIQUIDS FORM AN IDEAL SOLUTION. WHAT MUST BE THE MOLE FRACTION OF BENZENE IN A TOLUENE SOLUTION WHICH BOILS AT 89.62 DEG C AT 760 MM HG?

6. A SOLUTION OF 9.795 G OF A CERTAIN NON-ELECTROLYTE IN 482 G OF WATER FREEZES AT -0.0954 DEG C. CALCULATE THE MOLECULAR WEIGHT OF THE NON-ELECTROLYTE.

7. HOW MANY GRAMS OF $C_{10}H_8N_2$ MUST BE ADDED TO 290.99 G OF WATER TO GIVE A SOLUTION WITH A VAPOR PRESSURE OF 0.116 MM HG LESS THAN THAT OF PURE WATER AT 33 DEG C. THE VAPOR PRESSURE OF WATER AT 33 DEG C IS 43.0 MM HG. (THIS IS A NON-VOLATILE SOLUTE.)

TEST 10

1. 100.0234
2. 9.35E+01
3. 2.64E+00
4. 4.601E+02 TORR
5. 6.39E-01
6. 3.96E+02
7. 6.81E+00